PUBLIC ROADS

A JOURNAL OF HIGHWAY RESEARCH

UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF PUBLIC ROADS

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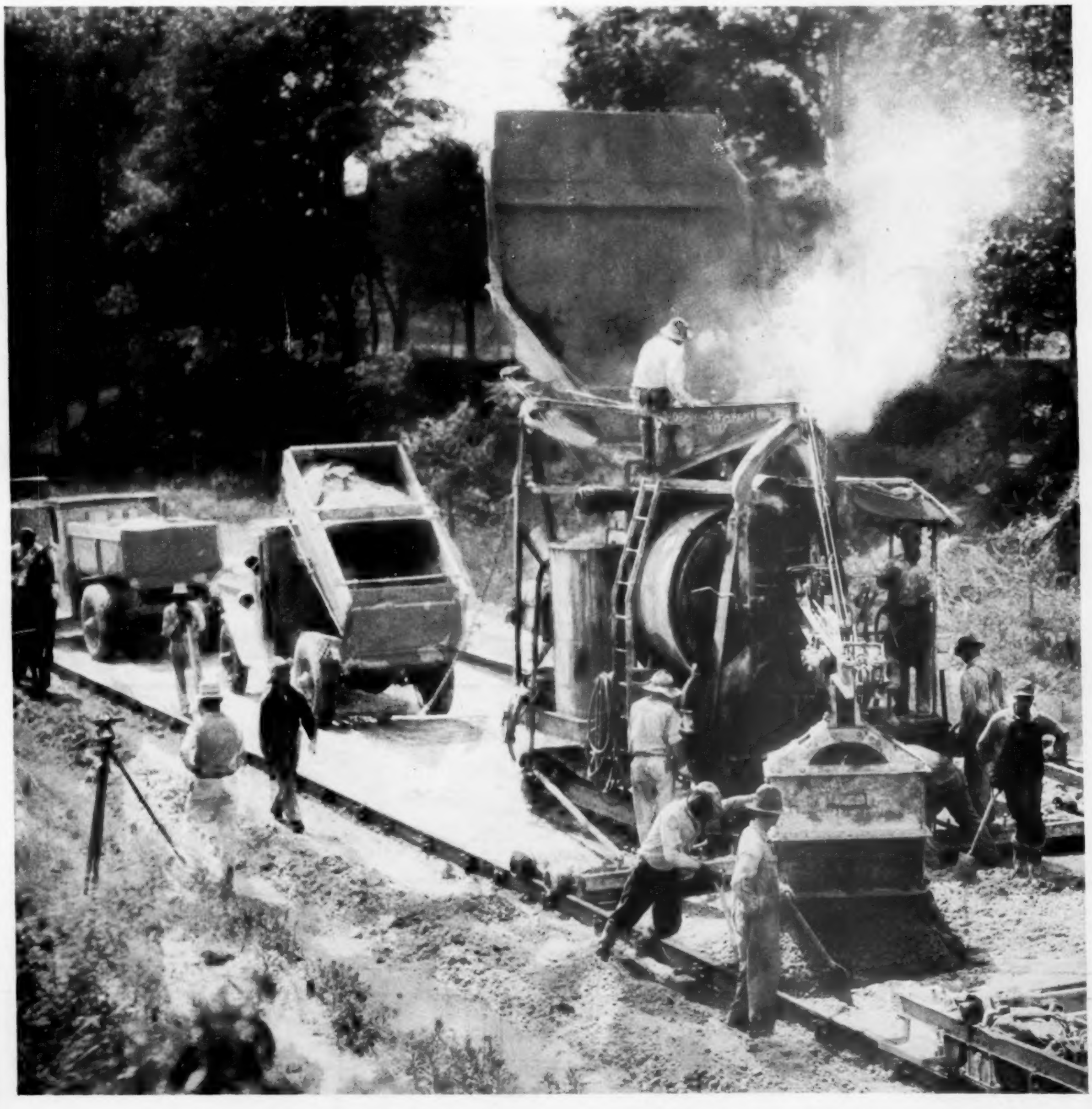

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VOL. 11, NO. 12 **FEBRUARY, 1931** **G. P. St. CLAIR, Editor**

TABLE OF CONTENTS

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NORTH CAROLINA COUNTY ROAD AND FINANCE SURVEY

Report of a Cooperative Investigation by the North Carolina State Highway Commission, the North Carolina State Tax Commission, and the United States Bureau of Public Roads.[1]

> The cooperative survey of county road mileage and finance which was conducted in North Carolina during the latter half of 1930 revealed the existence of numerous defects in organization and administration. It is believed that many of the conditions found in North Carolina are characteristic of other counties throughout the United States. For this reason the text of the report on this survey is presented here, in the hope that it will prove of value to those interested in promoting efficiency and economy in the construction, maintenance, and financing of county roads. A number of tables giving data for the individual counties, which were included in the report as submitted to the Governor of North Carolina, are omitted here. With this exception, all the material which appeared in the original report is included in this article.
>
> The first part of the report discusses the manner in which the survey was conducted and the data which were obtained from the various counties. In the second section a résumé is made of the facts disclosed by the investigation. The third section consists of recommendations for the improvement of conditions in the counties of North Carolina.

UNDER the general direction of Gov. O. Max Gardner, a cooperative survey of county road mileage and financial operations of the counties of North Carolina was undertaken July 16, 1930, by the State Highway Commission of North Carolina, the State Tax Commission of North Carolina, and the Bureau of Public Roads of the United States Department of Agriculture.

The purposes of the survey were to ascertain for each county the mileage and location of county and township roads, and to determine the amounts and sources of road revenue, the purpose for which expenditures of road revenue were made, the amount of bonded indebtedness outstanding for road purposes, rates of taxation levied for road purposes, and other information which would be of use in a general examination of the local road finance and management in North Carolina.

Because of the limited time available for this investigation, certain features of the survey were made on a reconnaissance basis. Thus, road mileage was measured with speedometers, road locations were determined from existing maps, and where tax settlements had not been made by the sheriffs a reasonable estimate of probable collections made by county officials was accepted.

The actual work of collecting road-mileage data and the preparation of the maps was undertaken by the State highway commission, operating through the nine divisions of the commission. The collection of data with regard to highway income, expenditures, bonded indebtedness, tax rates, etc., was undertaken by the State tax commission and the United States Bureau of Public Roads, operating through field parties which visited each county seat and obtained data from the county records. The task of analyzing county records was greatly simplified by the fact that the legislature of 1927 created the county advisory commission, which had set up for nearly all counties a standard accounting procedure which was accepted and operated by the counties in a very creditable manner.

North Carolina, with a total area of 52,426 square miles, has a land area of 48,744 square miles, which has been used as a basis for comparison with road mileage. This area is divided into 100 counties, with an average area of 487.4 square miles.

ORGANIZATION

The financial affairs of each county are administered by an elective board of county commissioners consisting of three, five, or seven members. The total number of commissioners for all counties during 1930 was 407.

The county board fixes tax levies, sets up and approves budgets, and, in general, under the statutes, exercises the powers of a legislative and administrative body. In 24 counties the board also serves as a county highway board having jurisdiction over the expenditure of highway funds. In 44 counties the highway board consists of an independent membership composed of from one to seven members. These boards supervise expenditure for road purposes only and do not have power to fix tax rates. In 26 counties some form of township road organization exists, composed of from one to three members with varying powers over road matters. In several counties the township boards levy taxes, collect and expend the proceeds without county supervision. In others, the levy is fixed and collected by the county and expended by the township.

County engineers appointed by the county boards are found in 25 counties. In 18 of these counties, road superintendents are also employed. In 49 counties actual supervision of road work is vested in a county superintendent of roads, who is employed by the board and receives instructions from that body. In the remaining counties the members of the board of commissioners also serve as heads of the road forces in the townships comprising their respective districts.

The lack of uniformity in local road organizations is due primarily to special legislation enacted by the legislature permitting deviations from a standard organization, or to the enactment of special laws which set up new forms of management and organization.

FINANCES

The local road program of the fiscal year ending June 30, 1930, was financed almost entirely from local tax levies. Although approximately $3,000,000 was made available to the counties from State funds, only 15 of the 100 counties elected to spend their share on roads, the remainder applying their contribution to the debt service fund used to pay interest and principal on outstanding county obligations.

The legislature of 1929 made available to the counties the proceeds of the additional 1-cent tax on gasoline. This sum, with $500,000 from the regular State highway fund, comprised the $3,000,000 fund available to counties for expenditure for road purposes under the supervision of the State highway commission or to be

[1] This survey was executed during the period July 16 to Dec. 15, 1930, by the personnel of the organizations cooperating. The work was carried on under the direction of R. A. Doughton, chairman of the State highway commission, and A. J. Maxwell, chairman of the State tax commission. The following employees contributed full-time service during this investigation and assisted in the preparation of the final report and maps: Messrs. T. M. Denson and C. M. Sawyer, of the State highway commission; Fred W. Morrison and Prof. Mark C. Leager, of the State tax commission; and George G. Clark, A. E. McClure, and W. A. Blanchette, of the U. S. Bureau of Public Roads.

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expended for retirement of outstanding indebtedness under the supervision of the State debt commission.

Table 1, compiled from the records of all counties for 1930, shows the sums made available for county and township road purposes.

TABLE 1.—*Total funds available to all counties of North Carolina for road purposes during the fiscal year 1930*

1. Sale of road and bridge bonds		$100, 059. 36
2. Sale of notes [1]		338, 023. 60
3. Appropriations or transfers from other funds		124, 596. 44
4. Tax collections:		
Current year	$5, 461, 436. 63	
Previous years	276, 361. 25	
		5, 737, 797. 88
5. State funds contributed		283, 165. 14
6. Miscellaneous income		480, 834. 30
Total new funds for year		7, 064, 476. 72
Balance brought forward from preceding year		2, 705, 567. 69
		9, 770, 044. 41

From these figures it will be seen that support of local roads is dependent largely on local tax levies. These levies vary from 7 cents per $100 in Buncombe County to 75 cents per $100 in Ashe County, rates in general varying inversely with the wealth and population of the counties. The total road taxes collected during 1930, current and delinquent, represented about 19.3 cents per $100 for the State as a whole. The average tax rate levied in the 10 wealthiest counties for 1930 was 14.7 cents on the $100, with the highest rate, 19¾ cents, in the tenth county. The other side of the picture is shown in the 10 poorest counties, with levies averaging 21.2 cents and a range of from 7 to 65 cents on the $100.

Of the 26 counties levying township taxes, which amounted in 1929 to a total of $951,667, total levies in 14 counties amounted to only $94,826, or an average of less than $7,000 per county. In the remaining 12 counties levying $856,841, the average was $71,400 per county, with three exceeding $100,000 per county.

The fiscal year for counties begins July 1 of each year. Property taxes are not due until November 1 following, with the result that in most counties the road administrator is confronted during the period of most active work with an empty treasury and in many cases with a deficit. To relieve this condition county boards may sell "tax-anticipation warrants" in amounts not to exceed 80 per cent of the taxes levied. The restriction on the amount of notes sold was placed by the legislature of 1927 and was intended to correct abuses of note selling, which in many instances in previous years were not repaid but were converted into long-term bonds.

BOND ISSUES

The total amount of county and township road bonds outstanding on June 30, 1930, as nearly as could be determined from county reports, was $100,066,572. These bonds, in general, were of the sinking-fund type with 20 to 30 year terms, bearing interest at rates ranging from 4½ per cent to 6 per cent per annum. The weighted average rate for all issues was 5.247 per cent. This total includes only those bonds appearing on the records as issued for road and bridge purposes. These bonds covered loans and donations to the State highway commission, costs of construction of county roads and bridges, and deficits in the road funds of the counties. For many years it has been a more or less general practice of county boards of commissioners to cover a deficit in the road fund with notes which were later covered by bonds. Such road and bridge bonds as have matured and have been covered by issues of funding bonds have, in general, lost their identity on the county records as road funds. Such bonds do not appear in the above total. No reliable estimates of the amount of such funding bonds outstanding properly chargeable as road bonds could be obtained.

The information regarding amounts in sinking funds for the retirement of outstanding bonds was somewhat confused, because of the rather general practice of treating all bond issues as a common debt with a common sinking fund for all. Again, in many instances, casual inquiry developed that sinking funds had been borrowed for other departments of the county or invested in real estate loans, which are in some instances in the status of frozen assets. In general, detailed, accurate information in regard to sinking funds for road and bridge bonds was not available during the progress of this survey. On account of the wide powers vested in local officials by statutes and special legislation to issue bonds, and the promptness with which interest charges have been paid, a ready market for such securities has been found. Therefore, many improvements which might have been financed from current revenues by the imposition of an increased road and bridge tax have been met by the issue of notes which have been later converted into bonds.

County board relations with the State highway commission have brought about transfers of county funds to expedite the construction of particular sections of the State highway system. In general this procedure has involved a loan to the State which has been later repaid, or an outright donation to the State. In a few instances sections of State road have been built by the counties and then transferred to the State highway system. County funds in the amount of $16,799,576.40 have been loaned to the State highway commission, of which only $4,770,651.28 is still outstanding. In addition to this sum the counties have donated to the State outright $8,772,869.93 without expectation of repayment. The State highway commission is making repayments as rapidly as funds become available.

Under the terms of recent State legislation new bonds and refunding bonds issued must be of the serial type and tax levies must be provided for the payment of principal and interest. During 1930 principal requirements of bonds maturing, both of sinking fund and serial types, amounted to $2,324 368, while interest requirements amounted to $5,249,407, giving a total of $7,573,775, a sum in excess of the annual county road expenditures for maintenance and almost as much as the costs of construction and maintenance combined.

Deducting from the outstanding bond issues the sums due from the State highway commission, the donations actually made to the commission in cash, and roads built, there still remains outstanding a sum of bonded indebtedness far in excess of the present worth of the highways remaining on the county systems. By far the greater part of the excess represents deficits from previous years; that is, ordinary road and bridge expenditures converted into bonds by way of notes.

Therefore, the present debt service levy, in part, represents a charge that should have been levied during the past decade when taxes were low and deficits were allowed to accumulate.

[1] Where notes were repaid during 1930, such items do not appear in these totals.

EQUIPMENT

By means of a questionnaire sent out by the North Carolina County Advisory Commission, an estimate of the road equipment owned by the counties and townships was obtained. These replies showed an estimated cost of equipment on hand to be $2,588,000. Of this amount $1,887,600 was located in 47 counties operating convict forces. The remaining $700,400 was located in the 53 counties dependent on hired labor for road upkeep.

It was not possible with the force at hand and the limited time available to make a check and appraisal of the equipment in each county, but interviews with field representatives of the State highway commission and study of county expenditures indicated that road equipment purchased was in many instances of the heavier and more expensive types. This may possibly explain the gasoline, oil, and grease bill in excess of $900,000 or $20 per mile per year for each mile of county road in the State, many miles of which showed no evidence of having benefited from regular maintenance.

CONVICT CAMPS

Forty-seven counties of the State maintain convict camps or stockades for the incarceration of misdemeanants and felons serving less than 10-year terms. The authority for the organization of county prisoners and short-term felons into county camps is found in chapter 24, articles 2 and 9, and chapter 70, article 4, of the consolidated statutes of North Carolina and numerous public-local laws applicable usually to a single county but occasionally to two or more.

The official in charge of a prison camp is generally termed the superintendent; or he may be the county superintendent of roads; or, in other cases, the county road engineer may exercise general supervision over the camp.

Due to the multiplicity of public-local laws, little uniformity as to organization of camps and utilization of inmates on road work exists. In general, able-bodied prisoners are placed in the road gang and utilized at the discretion of the superintendent.

The records of expenditures and road mileage show that few miles of high types of road surface—i. e., bituminous macadam or better—were constructed during the last year. Therefore, convicts were used largely for the maintenance, repair, and reconstruction of earth, sand-clay and topsoil types of road. Statements of camp officials and local and State road officials tended to establish the opinion that the use of prisoners under the supervision of armed guards on work of the latter type did not produce results at a low unit cost. Several reasons were assigned for this condition: First, the cost of guarding small bodies of men at work on maintenance or small repair jobs; second, the inefficiency of the prisoners; third, the difficulty of obtaining superintendents possessing the necessary knowledge of road building and maintenance combined with the ability to develop efficient work from the prisoners, the latter reason having the greatest effect on the results secured. Many superintendents strive to keep the prisoners at work, but in many counties more emphasis is placed on labor performed than on efficiency of the results secured.

Another vexing phase of the convict problem is the large number of short-term men, many of whom are diseased, who pass through the camp for 30 or 60 day terms. The labor of these men does not reimburse the county for court fees, clothing costs, medical attention and subsistence, all of which are paid from the road fund.

No figures were available as to the average number of convict camp prisoners in the State. Messrs. Steiner and Brown, of the University of North Carolina at Chapel Hill, estimated in 1927 that 2,500 were so confined. This estimate seems to be fair and reasonable. The total expenditure on account of convict camps in 1930, including all costs shown on the county books, was $1,289,686.57, or an average annual cost to the taxpayer of $515 per convict, using 2,500 convicts as an average. Wide variations from this figure may be found in individual counties due to differences in accounting procedure and efficiency in managing the camps.

EXPENDITURES

The total road expenditures of all counties and townships during 1930 reached a total of $8,233,280.93, excluding the transactions covering short-term notes which were executed and paid during the year. Following the arrangement of accounts recommended by the county advisory commission, the expenditures are listed in Table 2.

TABLE 2.—*Total road expenditures of all counties in North Caroline during fiscal year 1930*

Item	Amount	Percentage of total
1. General overhead expense	$271,856.41	3.3
2. Convict gangs	1,289,686.57	15.6
3. Maintenance of roads and bridges	2,725,807.93	33.1
4. Construction of roads and bridges	1,342,611.63	16.3
5. Equipment expense	1,371,651.48	16.7
6. Interest on short-term notes	70,745.78	0.9
7. Principal of short-term notes	94,903.74	1.1
8. Gasoline, oil, and grease	908,144.47	11.1
9. Miscellaneous expenditures (not classified in the records)	157,872.92	1.9
	8,233,280.93	100.0

These accounts were made up as follows: Under item 1, all expense and salaries for those road officials employed in or about the court house, including fees of county commissioners; under item 2, all salaries and expense incident to the convict camps as shown on county records; under item 3, all materials, salaries, wages, and other items entering into road maintenance; under item 4, all materials, salaries, wages, and contracts entering into road and bridge construction; under item 5, all expense incident to the repair and operation of equipment except gasoline, oil, and grease; under item 6, interest paid on short-term notes, the proceeds of which were placed in the road fund; under item 7, payments of principal of short-term notes carried forward from the previous year; and under item 8, all purchases of gasoline, oil and grease.

The last-mentioned item, comprising so large a part of the total expenditure, is reported as a separate account, because the records were not kept uniformly throughout the State, as in some counties all gasoline was charged to convict camps, in others to equipment expense, and in some instances to construction or to maintenance; and also to bring out the relationship existing between equipment on hand, the cost of repairs and replacements, and the cost of gasoline, oil, and grease used in operation. Equipment on hand was valued at $2,588,000; equipment repairs and operation except gasoline, oil, and grease, $1,371,651.48; and gasoline, oil, and grease, $908,144.47. The combination of the last two items equaling $2,279,795.95 is more than

25 per cent of the total local expenditures for construction and maintenance.

Another classification of accounts recommended by the North Carolina County Advisory Commission groups expenditures as shown in Table 3.

TABLE 3.—*Alternative classification of road expenditures for all counties*

Group	Amount
1. Personal services	$2,399,511.28
2. Supplies and materials	2,514,890.89
3. Other expenses including road contracts	2,408,693.15
4. Purchases of equipment other than replacements	708,452.04
5. Expenditures not classified	201,733.57
	8,233,280.93

A further analysis of these groups follows.

Under Group 1, the item of wages (labor pay rolls) leads with an expenditure of $1,713,111.83. Guards for camps cost $254,130.52. Salaries of superintendents amounted to $219,651.04, the remainder of the expenditure falling into small items.

Under Group 2, major expenditures are found as follows:

Gasoline, oil, and grease		$908,144.47
Food and provisions		321,319.38
Timber and lumber		213,043.63
Feed and animal supplies		177,903.56
Motor-vehicle supplies and parts		92,585.60
Hardware and paints		45,829.28
Medicine and drugs		19,761.49
Wearing apparel		78,074.92
Bedding and linen		18,794.18
Small tools		26,762.73
Tires and tubes		21,185.44
Household and janitor supplies		19,586.35
Road materials:		
Explosives	$17,940.98	
Cement	10,161.69	
Sand	8,556.34	
Gravel	21,989.40	
Brick	72.24	
Stone	35,283.03	
Pipe, tile, and culverts	117,314.56	
		211,318.24

The total of road materials purchased, as above stated, is very small, but it must be added that it does not include the materials used on construction contracts as these were not segregated in the county records. Other items in this group were small in amount and of little significance. However, unclassified items totaling $300,396.92 were found listed under this group in the accounts of the counties.

Under Group 3 outstanding expenditures were as follows:

Miscellaneous construction	$1,479,818.09
Blacksmithing and shoeing	11,423.80
Repairs to buildings, fences, etc	18,507.80
Repairs and replacements to equipment	357,288.61
Repairs to automotive equipment	124,797.07
Interest and discounts	62,591.44
Insurance and bonding	41,129.36
Miscellaneous (not classified)	241,361.49
Freight, drayage, and express	11,316.84
Awards and damages	10,911.23
Electric light and gas	10,960.06

Other small items less than $10,000 each make up the remainder of the expense.

Under Group 4 purchases were as follows:

Office equipment	$396.91
Automobiles	20,896.79
Trucks	172,997.61
Tractors	101,874.68
Wagons and harness	$2,434.85
Road machines	69,727.27
Other machinery and equipment	294,327.45
Livestock	6,261.00
Land	2,267.03
Buildings, structures, and fences	30,764.95
Rifles and guns	169.35
Books and libraries	3,306.65
Miscellaneous (not classified)	3,027.50

Group 5 includes all items in all counties which were not clearly classified on the records. In a very few counties it is still considered sufficient to merely record the amounts expended and the recipients, ignoring the value for administrative purposes of a statement of the kinds, classes, and amounts of things purchased. Other counties simply listed various purchases for which no subaccounts had been provided under the general heading "Miscellaneous."

Sufficient detailed records were kept in at least ninety-five of the hundred counties to present a reasonably accurate statement of the general road disbursements for the State.

ROAD MILEAGE

No accurate survey of the local road mileage has ever been made. The survey covered by this report was instituted about August 1 and field work was completed during October. Because of the short period of time available, short-cut methods were of necessity adopted. United States Soil and United States Geological Survey maps were available for almost all counties. These maps, of varying dates, showed all roads in existence at the date of survey. With these maps as a base, parties from the district offices of the State highway commission traversed by automobile each public road in each county, making speedometer records of the length of each, its type of construction, and its classification as A, B, or C according to its general traffic importance in the county system.

In order to preserve some measure of regularity of classification, a form of the type indicated below, defining the three classes of road and indicating the information desired, was issued for the guidance of road-survey parties.

North Carolina cooperative county highway survey for the fiscal year ending June 30, 1930

Major classification of county highways according to traffic	Miles	Percentage of labor, materials, and supplies used for annual maintenance
Class A—highways whose major purpose is to serve intercommunity traffic		
Class B—highways serving in approximately equal proportions farm and intercommunity traffic		
Class C—highways whose major purpose is to serve traffic between farms, mills, camps, etc., and roads of classes A and B		

Each map was reviewed at the central office of the commission in Raleigh. Connecting roads were brought into agreement at county lines and new maps, with a scale of 1 inch per mile, were prepared. Of these maps two are reproduced here for purposes of contrast. Figure 1 is a map of Mecklenburg County, a highly developed community with a close network of county roads. Figure 2 is a map of Clay County, which is sparsely populated and has a relatively undeveloped road system.

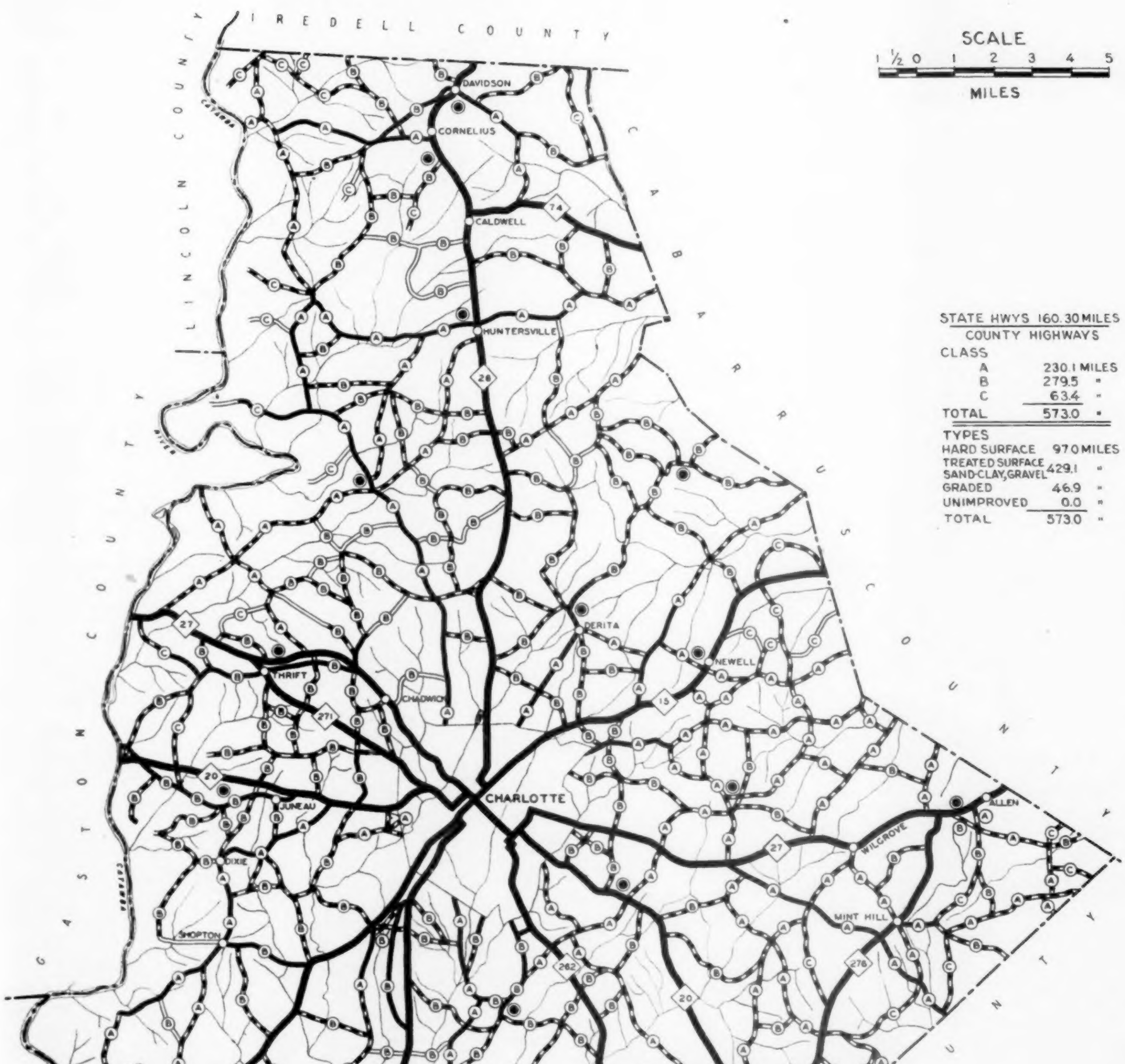

FIGURE 1.—MAP OF MECKLENBURG COUNTY, N. C., SHOWING STATE AND COUNTY ROADS

The survey made in 1926 by the United States Bureau of Public Roads, by visiting each county seat and obtaining estimates from county road officials, revealed a total mileage of 65,311.1. The results of the survey just made show a total mileage of local roads amounting to 45,090.5 Table 4 shows the mileages of each type of road as given by the two surveys.

TABLE 4.—*Comparative mileage of different types of road as shown by surveys of 1926 and 1930*

Type	Mileage	
	1926 survey	1930 survey
Earth roads, unimproved	20,359.0	11,807.7
Earth roads, improved	23,531.5	19,056.8
Sand-clay and top soil	17,845.6	12,260.2
Sand-clay, etc., treated		335.1
Gravel, chert, shale, treated and untreated	2,689.3	850.2
Waterbound macadam	237.2	175.1
Bituminous macadam	250.5	137.4
Sheet asphalt	104.2	71.8
Bituminous concrete	24.5	159.0
Portland cement concrete	236.8	203.7
Brick	32.5	33.5
Total surfaced mileage	21,420.6	14,226.0
Total mileage	65,311.1	45,090.5

The discrepancy between the two sets of figures may be attributed to two reasons—first, overestimation by local officials in 1926 and, second, transfers of county mileage to the State highway system. These transfers, according to the records of the State highway commission, are as follows:

Type	Miles
Earth roads	995.05
Topsoil, sand-clay, etc	1,405.60
Oil-treated roads (topsoil, etc.)	22.40
Gravel	64.95
Macadam	54.00
Asphalt	65.25
Concrete	47.35
Total	2,654.60

With a discrepancy of 20,220.6 miles between 1926 figures and the results of the 1930 survey, with 2,654.6 miles accounted for by transfer, it is apparent that the 1926 estimates were made on an optimistic basis. These discrepancies in mileage, varying from a few miles to an extreme case, in one county, of 250 per cent of the actual existing mileage as determined by the present survey, indicated on the part of county officials an astounding ignorance of the extent of the road mileage under their jurisdiction.

During the progress of the survey estimates were made by the field parties of the amount of construction and reconstruction performed by the counties during the year just closed. County mileage constructed and reconstructed during the fiscal year 1930 is shown in Table 5. The mileage improved, as stated above, represented 6¼ per cent of the total county mileage.

The classification of the roads into classes A, B, and C is admittedly an approximate segregation. However, in the absence of a complete traffic survey, it was believed that by this effort a classification which would be of some value in determining traffic flow would be secured. The results of this segregation and the estimated amounts expended for maintenance of three classes of roads are given in Table 6.

The sums expended for maintenance were obtained by deducting from the total, expenditures for construction, financing, etc., which left a sum of $6,567,146.86,

TABLE 5.—*Mileage of roads constructed and reconstructed by the counties of North Carolina during the fiscal year 1930*

Type	Constructed	Reconstructed	Total
Improved earth	699.5	408.5	1,108.0
Sand-clay and topsoil	619.3	785.8	1,405.1
Sand-clay and topsoil, oil treated	16.2	12.7	28.9
Gravel, chert, etc	126.9	84.6	211.5
Macadam	7.9	45.0	52.9
Bituminous macadam		3.6	3.6
Bituminous concrete	1.0		1.0
Portland cement concrete	9.3		9.3
Grand total	1,480.1	1,340.2	2,820.3

which, for the purposes of the survey, was classed as a maintenance cost. It is more than probable that some of the reconstruction or betterment costs, especially for work done on topsoil and sand-clay roads, are included in this sum. However, there were no data available from which to make such corrections; and for the purpose of obtaining the ratio of maintenance expenditures on the three classes of road, the effect of the inclusion of some items of expense for purposes other than maintenance will be small.

TABLE 6.—*Classification of North Carolina county roads according to traffic importance and analysis of maintenance expenditures on each class*

Class	Miles	Per cent	Annual expenditure for maintenance	Per cent	Average expenditure per mile
A	11,375.2	25.2	$2,343,133.28	35.8	$207
B	17,477.0	38.7	2,557,710.79	38.8	146
C	16,238.3	36.1	1,666,302.79	25.4	102
Total	45,090.5	100.0	6,567,146.86	100.0	146

The computation of average maintenance expenditures per mile assumes that the total expenditure was spread over the entire mileage of each class of roads. As previously stated, observations made during the course of the survey indicated that there were many miles, particularly of the less important roads, that apparently had not received the benefit of any systematic maintenance expenditure. The figures given in the table as average expenditures are therefore theoretical; and, as there was probably some mileage of each class upon which during the year there was actually no expenditure, the true average cost of maintenance for the mileage maintained would be somewhat higher than the theoretical averages.

With this explanation, the table shows that class A mileage, including the important county arteries, comprises about one-fourth of the county mileage. These roads should carry the greatest traffic and do receive a higher expenditure per mile for upkeep. It would follow in a well-coordinated road-improvement plan that the improved mileage would be found in classes A and B, as the total of surfaced mileage (14,226) is some 2,850 miles in excess of the total of the A group. However, as county boards are not permanent bodies, the plans of one board are not binding on their successors, and with each member of the board free to develop policies of the subdivision of the county represented by him, the road maps reveal a considerable mileage of class A road lacking improvement and a corresponding percentage of class C mileage which has been improved. This condition occurs throughout the State and is the inevitable result of the lack of definite program and the

expression of the individual judgment and preference of members of the county boards.

No attempt was made to determine the miles of the various types of roads appearing under the A, B, and C classifications, as time and sufficient personnel were not available. County roads, in general, are not built to the standards set by the State Highway Commission either in width, alignment, or grade. Of course, some exceptions may be found, but of the county mileage being taken over by the State, the greater percentage requires widening, easing of curves or actual addition of material.

Future construction by the counties will be of limited mileage annually for a number of years because of shortage of funds. Bond issues are few and small in amount, except for refunding purposes, and public sentiment, especially at this time, is unfavorable to an increase of road taxes.

County maintenance in 47 counties is handled by convict gangs and in 53 counties by hired labor. In general, roads falling in class A receive the first attention from the maintenance forces, with roads in class C receiving whatever funds may be left after the A and B roads are attended to.

With a large mileage of earth roads, improved and unimproved, and with topsoil and sand-clay the predominant types of surfacing, road maintenance becomes largely an operation of cleaning ditches and dragging surfaces. Labor utilized after cleaning and dragging have been performed at necessary intervals becomes labor more or less wasted as far as lasting improvement is concerned, and this aspect of convict utilization offers a fruitful field for future study. Some procedure should be developed to secure greater utilization of convicts on permanent improvements than is now being done in many counties.

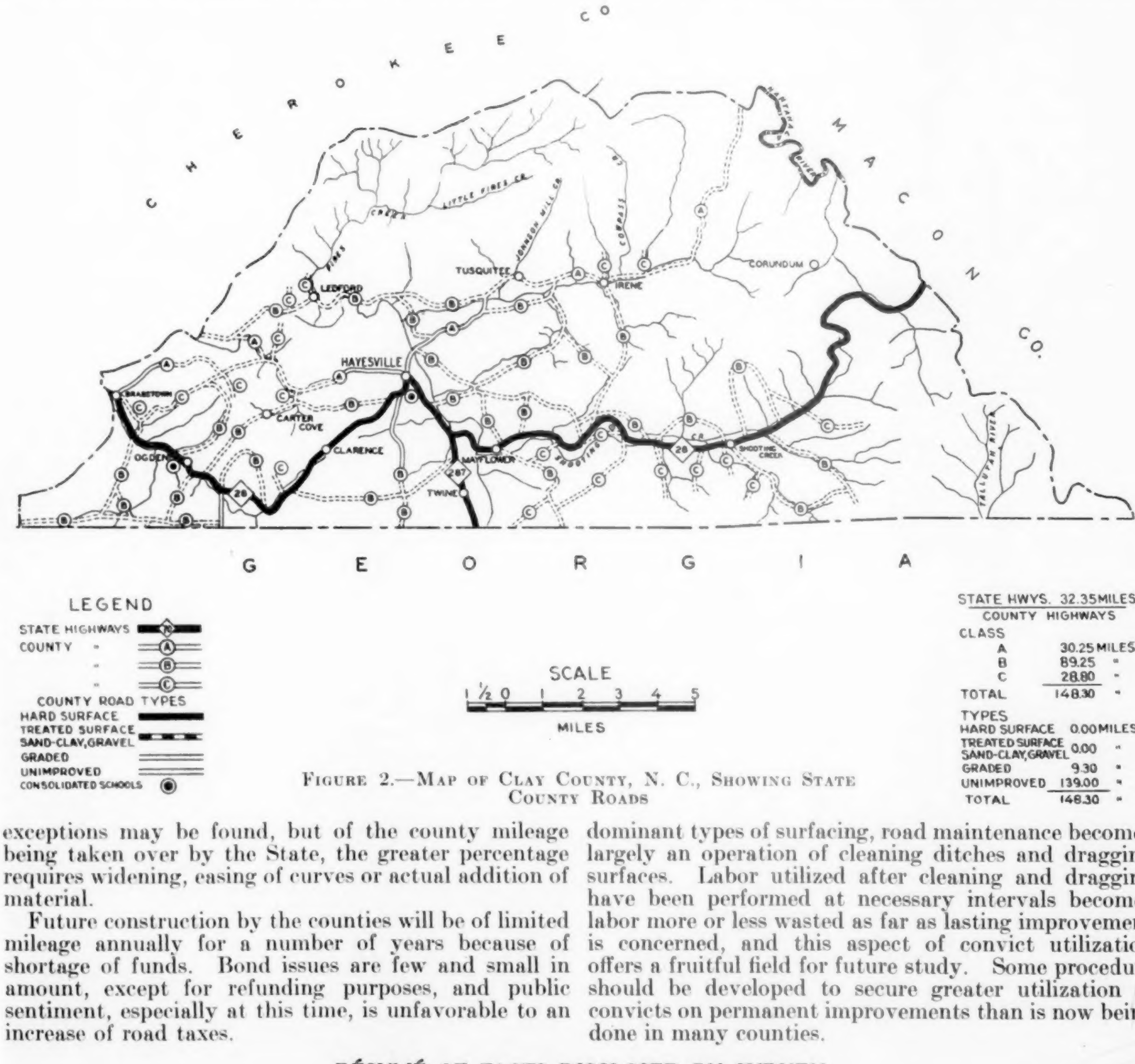

FIGURE 2.—MAP OF CLAY COUNTY, N. C., SHOWING STATE COUNTY ROADS

RÉSUMÉ OF FACTS DISCLOSED BY SURVEY

County road laws and procedures in North Carolina have not kept abreast of the actual changes occurring in volume and kind of traffic developed since 1868, at which time the present constitution of the State was adopted. For many years subsequent to the adoption of the constitution, horse-drawn traffic, the sole user of the highways, was small in amount and the radius of travel was short. Roads therefore were a local problem, used by the adjacent residents, and their condition was a matter of no concern to the residents of other sections of the township or county. Administrative road units comprising a township were better suited to local road needs in 1868 than they are at present, when automobiles may cross a township in 15 minutes and some counties in about a half hour. Rural highways are no longer a township matter, and, as this survey indicates, at least 25 per cent of the rural roads outside of the present State system are of intercounty importance. Again, township road officials, executing their offices as part-time occupants, with their regular vocations requiring their best efforts and attention, are not qualified to meet modern traffic needs and require-

TABLE 7.—*Estimated expenditures for public road maintenance by the counties of North Carolina ranked in groups of 10 according to assessed valuation*

Counties	Per $100 valuation	Per square mile	Per capita	Per mile of road
	Cents			
First ten	15.9	$408	$2.40	$328
Second ten	28.0	211	2.40	178
Third ten	27.0	137	1.92	137
Fourth ten	22.8	101	1.86	117
Fith ten	27.8	102	1.94	104
Sixth ten	29.8	93	1.92	104
Seventh ten	25.0	67	1.61	75
Eighth ten	29.6	60	1.90	95
Ninth ten	25.4	62	1.66	75
Tenth ten	32.6	44	1.94	90
Average	22.1	135	2.04	145

TABLE 8.—*Estimated expenditures for public road maintenance by the counties of North Carolina ranked in groups of 10 according to land area*

Counties	Per $100 valuation	Per square mile	Per capita	Per mile of road
	Cents			
First ten	26.8	$96	$1.97	$111
Second ten	23.6	144	2.22	158
Third ten	21.4	218	2.51	228
Fourth ten	22.8	103	1.77	113
Fifth ten	24.6	140	2.06	134
Sixth ten	21.5	71	1.41	82
Seventh ten	15.7	155	1.84	172
Eighth ten	22.0	208	2.38	208
Ninth ten	26.4	106	1.96	108
Tenth ten	18.5	108	1.74	125
Average	22.1	135	2.04	145

ments with the full use of modern equipment and procedure found so useful in the construction and maintenance of State highway systems.

COUNTY ROAD EXPENDITURES ANALYZED

It is at least an open question as to whether or not there are too many counties in North Carolina. Ten counties contain 42 per cent of the assessed valuation of the State, 20 contain 56.7 per cent, 30 contain 67.8 per cent, and 40 contain 76.5 per cent. This situation reveals that 60 counties contain only 23.5 per cent of the wealth, with the result that fixed charges necessary to maintain a county seat and the officials required by law imposes a tax upon property far greater in percentage than in the counties of the first groups. The effect of this condition is shown in the analysis of the road problem given in Tables 7, 8, 9, and 10. In these tables the 100 counties are ranked in groups of 10 on the basis of the four major factors, assessed valuation, area, population, and road mileage; and the estimated expenditures for public road maintenance are analyzed in relation to these four factors. The same total of $6,567,146.86 was used in these comparisons as was used elsewhere in this report as being the sum actually expended for upkeep of existing roads.

These analyses show that per capita expenditures are highest in the richest and poorest counties, while the tax on property is at its lowest rate in the richest counties and highest in the poorest counties. It is apparent that a low tax rate in the wealthy counties produces sufficient funds to carry out maintenance with a surplus for construction, while, on the other hand, the poor counties are compelled to raise their rates in order to provide for the absolutely necessary road-maintenance requirements.

TABLE 9.—*Estimated expenditures for public road maintenance by the counties of North Carolina ranked in groups of 10 according to population*

Counties	Per $100 valuation	Per square mile	Per capita	Per mile of road
	Cents			
First ten	16.9	$338	$2.33	$274
Second ten	29.2	199	2.32	175
Third ten	22.2	164	1.95	149
Fourth ten	23.6	93	1.80	99
Fifth ten	27.1	100	1.97	122
Sixth ten	23.4	82	1.70	83
Seventh ten	28.4	98	1.95	117
Eighth ten	27.3	57	1.81	88
Ninth ten	24.5	58	1.71	82
Tenth ten	32.0	47	2.30	93
Average	22.1	135	2.04	145

TABLE 10.—*Estimated expenditures for public road maintenance by the counties of North Carolina ranked in groups of 10 according to road mileage*

Counties	Per $100 valuation	Per square mile	Per capita	Per mile of road
	Cents			
First ten	21.6	$148	$1.94	$123
Second ten	23.5	209	2.40	172
Third ten	19.3	208	2.36	212
Fourth ten	24.6	134	2.00	142
Fifth ten	20.4	110	1.80	128
Sixth ten	22.8	139	2.13	151
Seventh ten	29.6	89	1.91	102
Eighth ten	24.8	83	1.88	121
Ninth ten	20.5	59	1.60	101
Tenth ten	20.5	67	1.92	167
Average	22.1	135	2.04	145

CONVICT CAMPS AND ROAD EQUIPMENT

Two of the largest items of cost in counties that employ convicts are the maintenance of convict camps and road equipment. The relation between the cost of maintaining the convict camps and the mileage of roads in a county, and the similar relation between the value of machinery owned and mileage of road, may be considered to represent the relative sufficiency of the convict establishment and machinery owned. A county in which these ratios are high may be considered as relatively fully equipped; one in which they are low must be considered as less fully equipped in respect to both convict forces and road machinery. There is in the various counties a wide variation in this relationship, indicating a very considerable variation in the sufficiency of the labor supply and machinery equipment for the road maintenance requirements of the several counties.

Thus, in New Hanover County the cost of convict camps per mile of road in 1930 was $326.70, while that for Harnette County was $2.44. The average cost of convict camps for all counties using them was $47.27. Among the counties using convict camps, New Hanover County showed the highest value of machinery owned per mile of road, $398; Duplin County, with $14.90 per mile, showed the lowest value. The average value of machinery owned per mile of road by counties using convict camps was $69.30. Among the counties not using convict camps, Onslow County had a value of machinery owned of $181.50 per mile of road; Alleghaney County had only $3.03 per mile. The average value of machinery owned per mile of road by counties not using convict camps was $39.30.

It is not necessary to go into the question of what constitutes adequate equipment. It is sufficient to point out that, as the character of the work done in the

various counties in North Carolina does not differ greatly, certain counties are obviously much more fully equipped to do the work than others. Some may be overequipped; some may be underequipped. The investigation that has been made has not been sufficiently complete and searching to determine with exactness the optimum equipment in any case; but the facts gathered do indicate that there is wide variation in relative adequacy of such equipment.

In the relations of convict camp costs and machinery value to assessed valuation of property, a similar wide variation in the ratios for the several counties was observed. Again, it is not necessary to consider at this time what would be a reasonable ratio; it is sufficient to note the variation in these ratios, which may be considered as measuring the relative weight of the burden represented by the cost of convict camp maintenance or machinery ownership, as the case may be.

In Buncombe County the cost of convict camps per $100 assessed valuation was 10.5 cents; in Cleveland County only 1.6 cents. The average cost of convict camps was 5.6 cents per $100 assessed valuation. Among those counties using convict camps, the value of road machinery owned in Scotland County was 24.2 cents per $100 valuation, while that in Gaston County was valued at 2.0 cents per $100 valuation. The average value was 8.2 cents. Among those counties not using convict camps, Onslow County, with 75.0 cents, showed by far the highest value of machinery owned per $100 valuation; while Mitchell County, with 0.1 cents, showed the lowest value. The average value for this group of counties was 10.5 cents per $100 valuation.

It may be further observed that in certain counties the burden of machinery ownership is relatively heavy, although the value of machinery owned per mile of road is relatively low; and that in other counties in which the value of machinery per mile is relatively high, the burden represented by such ownership is relatively low. Similar comparisons may be made in respect to the cost of convict camp maintenance.

REDUCTION IN NUMBER OF COUNTIES DESIRABLE FROM ECONOMIC VIEWPOINT

In the conditions brought to light by these comparisons lies the crux of one of the most serious problems of local highway administration in North Carolina, as in other States. It is clear that the root of the difficulties springs mainly from two facts: (1) That the county unit is not sufficiently large to include areas of rich and poor development within the same administrative borders; and (2) that the area of the average county and the extent of its road mileage are not sufficient to permit of full utilization of the force and equipment required for economic highway operations.

Thus, the small, wealthy county is not much more favored than the large and poor county. Though the latter is likely to suffer economic loss by reason of the poverty of its equipment and resources, the former is almost equally susceptible to loss by reason of the incomplete utilization of a rich endowment.

Considerations of this nature apply not only in the field of highway operations but in all other phases of county administration as well. They suggest that it would be desirable that study be made of the need for continuance of the present number of counties. With the present facilities for travel provided by the State highway system, at least half of the present number of counties could be consolidated and the residents of the larger counties would be in a closer touch with the county seats than the inhabitants of the present counties were ten years ago.

With respect to highway administration, similar advantages would accrue from a pooling of convict forces and machinery for the common use of several counties comprising a group of sufficient size to permit of an equalization of the financial burden and a more complete utilization of resources. As a practical measure it appears that the grouping represented by the 20 judicial districts of North Carolina merits careful consideration.

In the fact that county authorities were so unfamiliar with the highways under their control as to have reported in 1927 a total mileage exceeding by over 17,000 miles the mileage discoverable in 1930; and in the further fact that such improvements as have been made have been distributed apparently with little regard to the relative importance of the highways; in these facts revealed by the survey there is more than in intimation of inefficiency in county administration as at present organized.

In the enormous total expenditure for gasoline, oil, and grease there is strong evidence of waste and maladministration. In the practice of bonding for ordinary annual expenses of maintenance and repairs, there is strong evidence of the need of supervision by competent financial authority.

It is also evident that a part of the cost of State and county law enforcement is being paid under the guise of road expense. There is no reasonable excuse for the payment of criminal court costs from highway funds. Whether or not it is possible, in view of the constitutional limitation upon property taxation, to correct this anomaly is a question that deserves consideration.

Ad valorem taxes collected during 1930, including current and delinquent taxes, imposed a burden for the State as a whole of 19.3 cents for $100 valuation. Ninety counties imposed rates of less than 35 cents, while seven counties levied taxes at rates ranging from 39 cents to 75 cents per $100. These rates, in general, are very moderate and the tendency to the higher rates is observed in those counties whose necessity for existence may be questioned.

Additional funds, if required for local road purposes, should be secured by additional local taxes. The State gas tax and motor vehicle fund has been reduced to the point where further diversions of funds to local purposes would endanger the present State plan of financing, constructing, and maintaining the State highway system. The present gasoline tax rate is now 5 cents per gallon, and this approaches the refinery price of gasoline. Additional gasoline taxes if imposed would tend to become a sales deterrent, probably reducing the income derived from that source.

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RECOMMENDATIONS

1. It is recommended that the present law giving counties the option of using their allocation of gasoline tax for general county debt service or for road purposes be amended so as to limit the use of such funds to road purposes. This law now requires that expenditures of the proceeds of the 1-cent gasoline tax for local road purposes be made under the supervision of the State highway commission. The gasoline tax is imposed upon motorists to provide for highway improvement and upkeep, and a diversion of these funds to other purposes should not be made.

2. Recent additions of county roads to the State highway system have created a condition whereby the State highway commission, with its present supply of funds, will not be able for many years to improve in accordance with traffic requirements the mileage now under its control. Further additions to the present State highway system or diversions from the State highway fund to other purposes should not be made.

3. This investigation reveals that under the present county and township organizations road funds are, in many instances, expended without regard to the traffic importance of the particular roads improved. To remedy this condition provision should be made for a classification of local roads on the basis of traffic surveys and other investigations by State and local officials working in cooperation, and for the development of a financial plan to provide for the progressive construction and annual maintenance of the several classes consistent with the resources available and the traffic importance of each class. Pending the development of such a plan, there should be no increase of taxation for local road purposes.

4. Machinery purchases, operation, and upkeep for local roads are the occasion of much uneconomical expenditure. Some adequate State supervision and control should be established so that necessary machinery purchases may receive the benefit of the reduction in price to be obtained by group purchasing, that the selection of machinery may be more in accord with the actual needs, and that large units of equipment needed for only occasional work may be moved from one point to another, to the end that waste by idleness of this class of equipment which now exists can be avoided.

5. It is apparent that efficient utilization of the present county convict forces presents great difficulties, especially in the ordinary maintenance of the roads, and it is likewise apparent that there are few counties that will have sufficient money available for construction purposes in the immediate future to give profitable employment throughout the year for their convict forces. It seems necessary, therefore, that in order to work county convicts economically they must be divided under two general groups, so that those who are classed as "honor prisoners,"—those who can be worked without guards—can be utilized in ordinary maintenance work by the counties; and that those prisoners who have to be worked under guard, and therefore in larger groups, may be administered under some plan of district organization composed of several counties operated under the control of the State prison. Local road organizations could then obtain from this district camp groups of prisoners from time to time for use in the construction of roads, when funds are available for that purpose; and the district prison camp could develop such other lines of work as would supplement the road work that was available.

6. All township and special road district organizations should be abolished at an early date, and all control over the roads now under their supervision should be vested in organizations of wider territorial jurisdiction.

7. Additional powers should be vested in the North Carolina County Government Advisory Commission over budget and accounting affairs in the counties. At present these powers are advisory. The addition of supervisory and regulatory powers to this commission would be of great value in further standardizing financial procedure and safeguarding public expenditures.

8. Plans should be formulated whereby a State purchasing agency may serve the local road organizations in the standardization and purchase of road equipment and supplies.

9. Finally, it is recommended that the State highway commission be charged with general supervision over improvement and maintenance of the roads classed as of major importance under the classification of local roads on the basis of traffic surveys, as proposed in paragraph 3.

TRUCK OPERATION AND PRODUCTION IN CONCRETE PAVING WORK

By Andrew P. Anderson, Highway Engineer, Division of Management, U. S. Bureau of Public Roads

CAREFUL studies on more than one hundred Portland cement concrete paving projects throughout the United States show that an average of 17 per cent of the time during which the construction crew is out on the road ready to work is actually lost because of insufficient supply and faulty operation of the hauling equipment. The function of the hauling equipment on a concrete paving job is simply to transport the batches from the material yard to the mixer skip at the rate at which they may be utilized by the paver. To perform this function effectively should not be very difficult; and yet its inefficient conduct is probably the reason for more losses in profits and more failures of contractors than any other one thing.

In order to obtain a better insight into this rather general difficulty and, if possible, to develop some concrete evidence as to how and to what extent these time losses may be reduced or eliminated, an intensive analysis was made of the accumulated field records of the production studies which have been made on actually going projects by the engineers of the division of management of the Bureau of Public Roads. These records now contain fairly complete data on more than a hundred concrete paving jobs on which trucks formed the hauling equipment and on each of which the studies cover a period of from one to three months. They are of sufficient volume, therefore, to be reasonably representative of present general practice under actual field conditions. The more pertinent facts disclosed by the analysis of these records, and especially by those accumulated during the past three years, form the basis of this article.

CONCLUSIONS OUTLINED

These facts seem to indicate clearly that good management should find it both possible and profitable to reduce materially the interruptions to continuous mixer operation which now arise on the average job, and that it should be both possible and profitable to eliminate by far the greater part of the interruptions arising from faulty hauling operations. While it will no doubt prove profitable to reduce considerably the delays due to occasional shortages in the supply of the hauling equipment, their entire elimination under present methods of operation will probably be impossible without unwarranted expenditures.

There is also ample evidence that the insurance provided against an occurrence of too many of the more expensive mixer delays due to fluctuations in the normal rates of operation justifies a certain apparent oversupply in the hauling equipment. The operation characteristics of the hauling units as well as all auxiliary equipment can readily be determined on any particular job, both as to their individual operation and as to their combined effect on job operation and rate of production; and, when these operation characteristics of the hauling units have been properly ascertained, the number of trucks required to supply the mixer adequately on the varying hauls from day to day can readily be determined.

Other points brought out in this study are that on short hauls the main factor in determining how many batches any given truck can deliver per hour is not primarily the road speed but the length of time the truck must spend in the yard and at the mixer during each trip; and that given equal road speeds and present normal operating conditions, a two, three, or four batch truck does not deliver to the mixer as many batches per hour as two, three, or four 1-batch trucks, respectively. It was found that on 122 concrete paving jobs on which trucks were used for batch hauling, the average length of haul was 2.65 miles. In view of these facts it is evident that the relative production efficiency of single-batch and multiple-batch trucks is one rather important factor which should be given full consideration in the selection of equipment for a given job.

The data indicate further that the present rather common practice of subletting the hauling of the materials on a batch-mile, square-yard, or other similar basis introduces interests which are often antagonistic instead of mutual, in that the largest possible profit from the hauling will be secured when the rate of production is held at a point at which the profits from mixing and placing the batches are actually considerably below their possible maximum.

CAUSES OF LOW PRODUCTION DISCUSSED

In order to obtain a clearer conception of the conditions under which the average concrete paving contractor operates, let us first list the main causes which contribute to keeping down his production. For practical purposes these can be grouped under two main heads: Less-than-capacity load on the controlling or key equipment, and the operation of this equipment at less than its maximum rate. The latter, by far the most common cause of low production, is generally due to various more or less frequent interruptions to the steady, continuous operation of the key equipment. These interruptions or delays are generally termed time losses. In our studies we have for the sake of clarity divided these time losses into two classes: First, those consisting of definite stops each 15 minutes or more in duration, and, second, those less than 15 minutes in duration. The extent of the time losses of the first class as found on the average job is shown in Table 1.

TABLE 1.—*Delays of the first class—Per cent of total available time lost by the mixer in definite stops, each 15 minutes or more in duration*

Cause of delay	Per cent of available time lost
Rain and wet subgrade	17.5
Moving plant set-up	3.5
Lack of materials	3.5
Lack of prepared subgrade	3.0
Inadequate supply and faulty operation of hauling equipment	3.0
Mixer trouble	2.0
Lack of water at mixer	2.0
Loading plant trouble	1.5
Miscellaneous causes	4.0
Total	40.0

After the contractor has obtained his contract, set up his plant, and assembled his crew, we can thus

predict that the average job will lose, for various causes, about 40 per cent of the available working hours in definite stops each varying from 15 minutes to days in duration. Nearly one-half of these time losses are each less than one-half day in duration, and thus directly affect both mixer and hauling equipment operation. But this is not the end of the troubles. The records also show conclusively that every job loses a considerable amount of time in minor delays or interruptions, each less than 15 minutes in duration. Furthermore, all these short-time losses occur with the full crew on the job and are thus proportionately much more costly than full-day losses when most of the crew is not paid. The average of these minor time losses based on an analysis of 122 jobs is shown in Table 2.

TABLE 2.—*Delays of the second class—Average time lost to the mixer for minor delays or interruptions less than 15 minutes in duration, expressed in percentage of the net working time, or total available time minus all time losses 15 minutes or more in duration*

Cause of delay	Per cent of net working time lost	Per cent of total working time lost
Hauling equipment, supply	2.3	1.4
Hauling equipment, operation	7.9	4.7
Hauling equipment, dumping	2.0	1.2
Lack or trouble with water at mixer	3.2	1.9
Subgrade delays	2.7	1.6
Mixer operator	2.1	1.3
Mixer trouble	1.9	1.1
Lack of materials and supplies in place	1.1	0.7
Finishing	0.7	0.4
Miscellaneous	2.1	1.3
Total	26.0	15.6

Many of these second-class delays or minor time losses, and frequently most of them, are of very short duration, but are usually repeated every cycle, so that their total often becomes astonishingly large. Furthermore, all these losses occur with the full crew on the job and are thus proportionately much more costly than full-day losses when the crew is not paid. Table 2 shows that the average job loses 26 per cent of the net working time or 15.6 per cent of the total available time in delays and interruptions none of which are as long as 15 minutes and most of which are each of only a few minutes or seconds in duration but of a constantly recurring nature. In these minor time losses 12.2 per cent of the net working time or 7.3 per cent of the total working time are due to the hauling equipment. These losses are divided on a percentage basis as follows: 19 per cent, or about one-fifth, arise from actual shortage of the hauling equipment; 17 per cent, or about one-sixth, from dumping the batches; and the remaining 64 per cent, or nearly two-thirds, from faulty or inefficient operation of the hauling equipment on hand. It is noted in Table 1 that 3 per cent of the total available time was lost due to the hauling equipment in stops of more than 15 minutes' duration. These naturally all occurred while the full crew was on the job and might better be included under the net working time losses. On this basis the time losses chargeable to the hauling equipment amount to approximately 17 per cent of the net working time, or 10 per cent of the total available time.

CONCRETE PAVING CONSTRUCTION DEMANDS SYNCHRONIZED OPERATION

In order better to understand why it is that the hauling equipment is the cause of such large and persistent delays to the continuous operation of the mixer, it is necessary first to realize how the modern concrete paving job is conducted and what factors or conditions influence or control its rate of production. In a report published in 1925[1] it was shown that the process of constructing a concrete pavement is essentially a continuing operation in which the maximum rate of production is fixed by the requirements which determine the length of the mixer cycle; and that every interruption to the steady, continuous operation of the paver on this cycle results in a decrease below the otherwise possible rate of production. There is, therefore, practically no opportunity for any appreciable variation in the rate of any of the numerous dependent operations. Nor is there any chance to anticipate the requirements of these different operations, except at the loading plant, where there is usually some opportunity to provide sufficient storage of materials to eliminate the delays which might otherwise occur due to switching or the nonarrival of cars.

From this point on all operations are closely interdependent. The materials must be proportioned, loaded, and hauled to the paver at a rate determined by the duration of the mixer cycle. The operations of finishing and curing can not be allowed to fall behind, nor can those of preparing the subgrade, setting the forms, placing steel, and forming joints be allowed to lag, but all must proceed at least at the general rate set by the mixer.

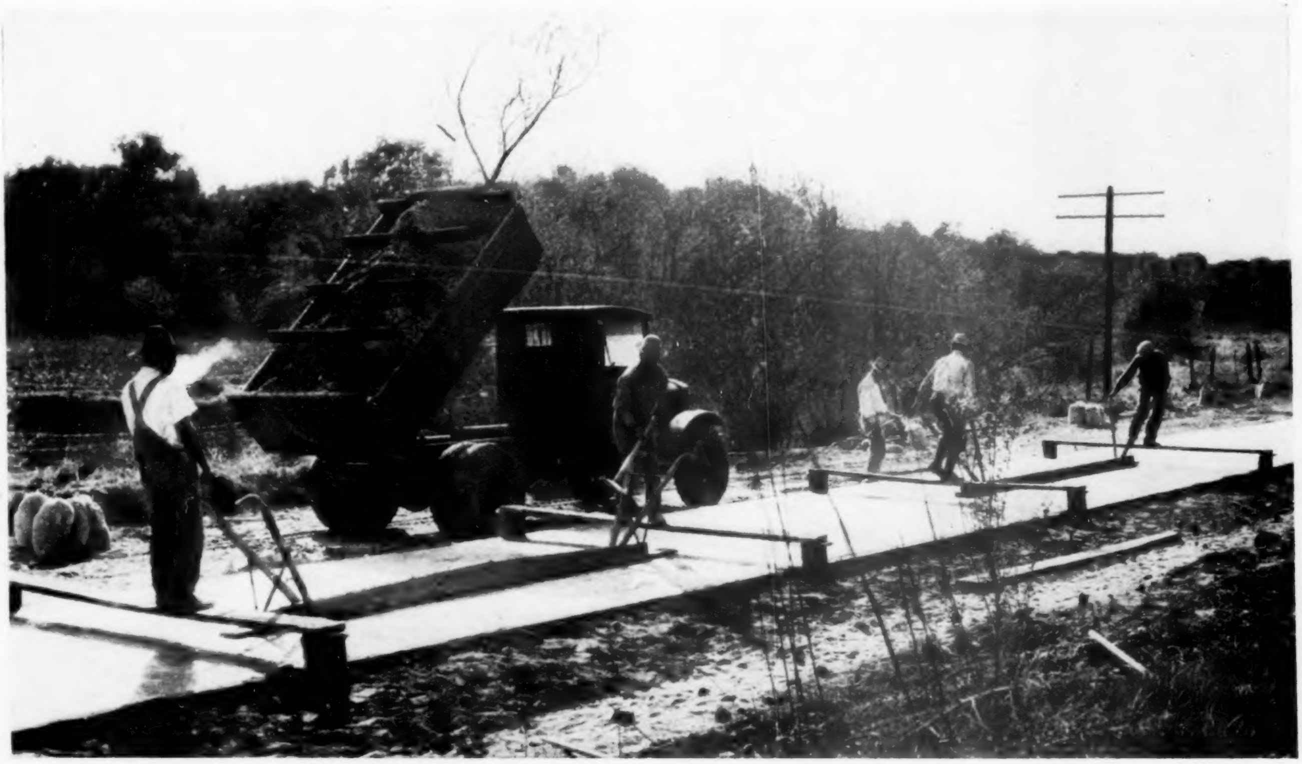
Losses of time occasioned by lack of coordination between the various operations involved in the paving process are irretrievable. Not even the loss of a single batch from the given maximum rate during one hour can be made up by more rapid operation during the next hour or the next day. If, for example, the mixer cycle is 75 seconds, the maximum possible rate is 48 batches per hour; and a production of, say, 45 batches during one hour can not be made good by a production of 51 batches during the next hour. A batch lost is a batch lost beyond recall.

Such decreases in production would not be a very serious matter were it not for the fact that, exclusive of materials and hauling, the daily or hourly cost of operating a concrete paving plant is practically constant, whether production is at the maximum possible rate or at almost any fraction thereof, so long as it is operating at all. The records which have been examined show rather conclusively that the average hourly cost of operating a modern concrete paving plant, exclusive of materials and hauling, is seldom less than $40 or $45 for every hour the paving crew is out on the road. If, for example, the mixing time and operating requirements permit a mixer cycle of 75 seconds and the hourly operating cost is $40.80, the operating cost per batch will be only 85 cents when the outfit is working at 100 per cent efficiency, and this cost will rise to $1.70 per batch when production falls to 24 batches per hour. This example emphasizes the importance of keeping the mixer in continuous operation on the lowest possible cycle.

Under the usual field conditions neither the mixer nor the hauling equipment can be operated for any extended period of time at 100 per cent efficiency. Theoretically, the mixer can be operated continuously on some definite cycle determined in part by its mechan-

[1] "Efficiency in Road Construction," by J. L. Harrison, PUBLIC ROADS, Vol. 6, No. 9, November, 1925.

ical condition and the skill of the operator, but mainly by the specifications and working methods required. In practice, neither truck nor mixer operation ever continues for any length of time at this maximum possible rate, and still more seldom do both attain this rate simultaneously. A large number of causes seem to conspire to prevent perfectly coordinated operation. As the rate of maximum production is approached, the difficulties of maintaining this all-essential degree of coordination multiply at an amazing rate. This does not mean that highly efficient operation is impossible, for the records show many cases where for a week at the time operation reached or closely approached 95 per cent of the theoretically possible maximum production.



In Order to Maintain a Short Mixing Cycle the Truck Body Must Be Hoisted to Dumping Position Before the Truck Is Backed to the Skip

HAULING OPERATIONS ANALYZED

For the purpose of giving the reader a better understanding of the reasons for those large, persistent, and expensive losses which are due to the hauling equipment, a somewhat detailed analysis will be made of the operating conditions of the hauling equipment and the functions with which it is associated or on which it is dependent. On the average well-managed concrete paving job, the hauling equipment cycle is about as follows: The truck on entering the material yard proceeds to the batcher to receive the sand and coarse aggregate. Usually some maneuvering is necessary in order to get the truck into position under the batcher; especially is this true where more than one size of coarse aggregate is required and two bins are used. If the truck carries more than one batch, it requires some movement before taking on each additional batch. The truck then proceeds to the cement platform where a stop is made to take on the cement bags. If bulk cement is used a canvass cover is usually spread and fastened down after the cement has been dumped on the batches, or a special container is provided. The truck then proceeds to the mixer.

The turntable is usually placed some 200 to 300 feet ahead of the mixer. The truck drives on the turntable, is turned 180°, backs off and proceeds in reverse toward the mixer. If sacked cement is used, it is a common practice for the men who empty the bags ts board the truck at the turntable and empty the bago on top of the batch while the truck is being turned and backed to the mixer. On some jobs a definite stop is made at some other point well ahead of the mixer, where the cement bags are all emptied before the truck proceeds to the turntable. If no turntable is used the turn is usually made somewhat further ahead of the mixer at a place where one or two forms are temporarily omitted so as to provide more room for maneuvering. If the previous truck has been unloaded the oncoming truck proceeds to the mixer, hoists the body to dumping position, and as soon as the skip is down backs into position on the skip. The dump man then drops the first batch; and the truck is driven ahead sufficiently to clear the skip. After the latter has been emptied and returned to the ground, the truck is again backed up and another batch is dropped. When the last batch has been dropped, the truck is immediately driven ahead, the body is lowered, and the truck proceeds to the material yard. On arrival at the yard, the end gates are closed and the truck is ready to begin the cycle of the next load.

TRUCK OPERATING TIME SUBDIVIDED INTO TIME CONSTANT AND HAUL

Truck operation may be subdivided into two parts. The first part includes the time spent while the truck

is being loaded at the material yard, plus the time required for turning, backing, and dumping at the mixer, plus such waits or delays as are necessary or incidental to both these operations. The total time required for these operations is designated as the time constant. The second part is the time spent in travel between the materials yard and the mixer, and is designated as the haul. The items going to make up the time constant will be considered first.

An analysis of the various steps comprising the truck-operating cycle shows considerable variations, but an examination of many truck-haul jobs studied during the past three years shows average values as given in Table 3 for the items which go to make up the truck time constant, or the time which the truck spends each trip in other operations than actual driving on the road between the materials yard and the mixer.

TABLE 3.—*Average truck time constant on all concrete paving jobs*

Operation or item	Time consumed, in seconds			
	1-batch truck	2-batch truck	3-batch truck	4-batch truck
Batcher plant:				
Loading sand and stone or gravel	15	59	114	190
Loading cement	28	80	106	110
Driving and maneuvering within yard	81	99	102	100
Mixer:				
Turning at mixer	68	75	64	93
Backing to mixer	56	77	70	75
Dumping batches	23	128	200	303
Waits or delays	141	178	292	417
Total time constant per round trip	412	696	948	1,288
Total time constant exclusive of waits	271	518	656	871

WELL-MANAGED JOBS SHOW MUCH LOWER TIME-CONSTANTS

While these are the average values for a large number of jobs and thus reflect the operating rates which might reasonably be expected on the ordinary job, they do not show what time is actually necessary to perform these various operations from day to day as indicated under actual field conditions. A smaller number of exceptionally well-managed jobs was therefore selected to afford a nearer approach to the theoretical values of these same items. These are given in Table 4.

TABLE 4.—*Average truck time constant on well-managed concrete paving jobs*

Operation or item	Time consumed, in seconds			
	1-batch truck	2-batch truck	3-batch truck	4-batch truck
Batcher plant:				
Loading sand and stone or gravel	12	48	90	150
Loading cement	24	47	73	102
Driving and maneuvering in material yard	42	54	60	65
Mixer:				
Turning at mixer	28	39	54	60
Backing to mixer	54	60	75	75
Dumping batches	19	110	157	265
Waits and delays	74	120	161	226
Total time constant per round trip	253	478	670	943
Total time constant exclusive of waits	179	358	509	717

It may be noted first that on the average job, as shown in Table 3, the total time constant is 30 to 50 per cent larger than the net time constant; or, in other words, that on the average concrete paving job about one-third to one-fourth of the actually observed gross time constant is due to waits and delays. Table 2 and the discussion following it show that on these jobs, so far as net working time is concerned, the mixer was operating at an average of about 26 per cent below its full capacity and to this loss of production the hauling equipment contributed about 12 per cent. If we include all hauling delays of more than 15 minutes duration, the figure becomes 17 per cent, or more than half the loss of net working time. This is in sharp contrast to the average time constant on the well-managed jobs. On these the total time constant is on an average nearly one-third lower than on the average job and only about one-fourth of the total time constant is due to waits and delays as compared with about one-third on the average job. Perhaps the most striking difference is the fact that on these well-managed jobs the mixer was operating at an average of only 13 per cent below full production. To this loss the hauling equipment contributed only about 4 per cent or one-fourth as much as on the average job. The records show one job on which during two full months only 1.96 per cent of the mixer time loss was due in any way to the hauling equipment.

DELAYS IN HAULING AND MIXER OPERATION NOT CONCURRENT

Another difficulty is that the operation of the hauling equipment is no more perfect than the operation of the mixer, and sometimes far less. Poor operation of the hauling equipment is quite as likely to occur when the mixer is functioning at its best and therefore requires perfect operation of the hauling equipment in order to avoid delays as it is when the mixer is functioning poorly and does not require so many batches per hour. The net effect of these nonconcurring operating rates results in a bunching of trucks at the mixer when the trucks are operating well and the mixer poorly, and a lack of batches when the conditions are reversed. The extent to which contract hauling tends to aggravate these difficulties will be discussed later.

Since 100 per cent operating efficiency is not long maintained by either mixer or hauling equipment, it becomes necessary to have a certain apparent oversupply of hauling equipment in order to prevent too many mixer delays due to waiting for batches during those periods when the mixer is going well and the trucks poorly. The data seem to indicate that the general practice is to have such a number of trucks that an average of from one to two batches will ordinarily be waiting at the mixer. In practice, this means that at times a dozen, or perhaps even more, batches will be waiting ahead of the mixer, while at other times the trucks will not be quite able to supply its demands. How and to what extent this present practice can probably be improved on will be discussed after we have examined some of the causes which affect truck operation at the batcher plant or material yard.

YARD LAYOUT AND OPERATION ANALYZED

One of the very common causes contributing to a arge time constant is a poor material yard layout. Usually there is no choice as to location, but too frequently the best use is not made of the location available. The general practice is to set up the batcher bins so that the trucks must turn and back under in order to receive their load. In fact, many bins are so built that a drive straight through is impossible. This is unfortunate, because turning, backing, and maneuvering a truck requires time which might otherwise be utilized in hauling batches. In fact, the yard layout

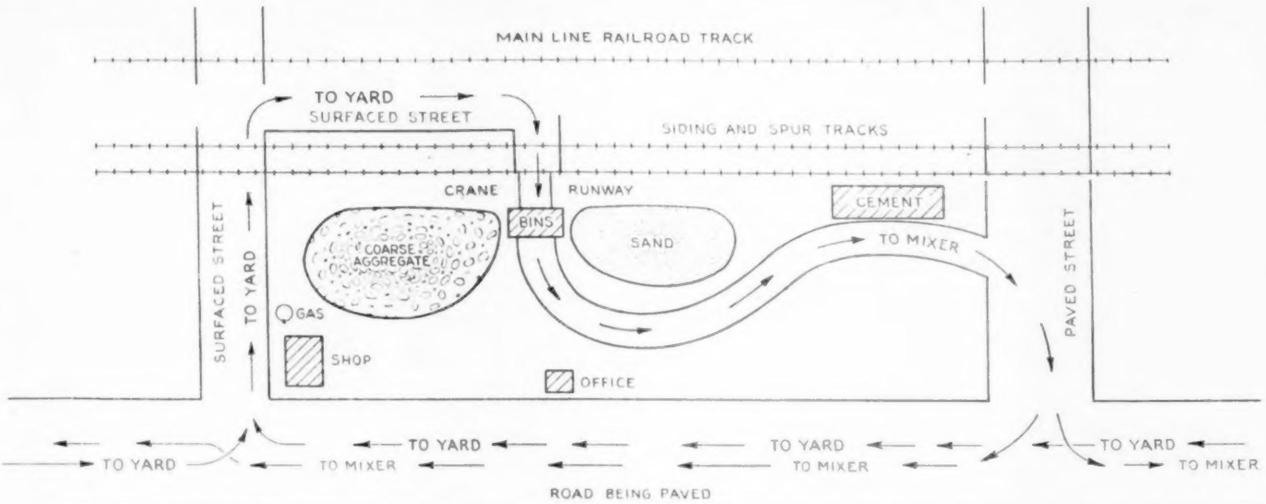


Figure 1.—Plan of a Good Yard Layout for Concrete Paving Work

and the routing of the several necessary operations should be planned as carefully as the performance of the several operations at the mixer.

The ideal yard layout would be one in which the trucks could enter at one end on a wide curve, drive straight under a loading bin having compartments for all the aggregates, pass on to a near-by cement-loading platform and storage shed, and then proceed on a tangent or easy curve to the main road. Figure 1 is a sketch of a yard layout which closely approached this ideal. The effect of the yard layout on the time constant is also shown in Tables 3, 4, and 9. In any yard layout the unproductive truck time should be reduced to a minimum, as every deviation from this attainment results in an inescapable penalty in the form of more expensive hauling.

A Sure Way to Get a Large Time Constant: Two Bins, Two Sizes at Each Bin, and Arrangement Such That Trucks Must Be Backed Under Both Bins

The modern bins and batchers can be operated so rapidly and with such regularity that there is usually no valid excuse for requiring the trucks to spend a long time at the loading plant. The modern batchers will ordinarily handle a 30 cubic foot batch of sand and one size gravel in 5 to 35 seconds, depending largely on how dry the sand is. If two sizes of coarse aggregate are used with a 3-way bin, the cycle will ordinarily be increased from 5 to 12 seconds. For 1-batch trucks the actual loading time is practially reduced to the time taken to dump the hoppers, as the filling and weighing can usually be accomplished while the loaded truck is passing out and the empty one is moving into position. Tables 5 and 6 give several values as found from time studies of batcher operation on representative jobs.

Table 5.—*Time of batcher operation as shown by studies of representative jobs*

Type of batching	Operation	Time in seconds
1-compartment batcher	Weighing sand	7.6
	Setting scales	4.1
	Weighing stone	5.7
	Dumping and returning	5.6
	Total cycle	23.0
Sand and 1 size coarse aggregate; 2-compartment batcher.	Weighing sand	7.3
	Weighing stone	8.9
	Dumping batch	7.1
	Total cycle	23.3
Sand and 2 sizes coarse aggregate; 2-compartment batcher.	Weighing sand	7.8
	Weighing No. 1 stone	10.0
	Weighing No. 2 stone	7.0
	Dumping batch	5.0
	Total cycle	29.8

Table 6.—*Batcher operation in loading 3-batch trucks by means of a 1-compartment weighing batcher*

Operation	Time in seconds		
	First batch	Second batch	Third batch
Discharging batch loaded while truck drives in	5.2		
Setting scales		3.0	3.1
Weighing sand		10.9	11.6
Setting scales		2.4	2.9
Weighing gravel		4.2	4.1
Discharging batches		5.6	5.5
Delays and waits, seconds		7.8	
Total time to load 3-batch truck, seconds		66.3	

Unfortunately, the yard layout and operation procedure is seldom such as to permit full advantage to be taken of the rate at which the batchers can be operated. Frequently the yard layout is such that vastly more time is consumed in maneuvering and driving within the yard than in the actual operations of loading. Table 7 is the average record of a large number of time studies on yard operation in one yard. Two-batch trucks were used with a two-bin set-up in a supposed

effort to facilitate the use of two sizes of coarse aggregate. A toll of nearly two minutes was exacted from every load which was passed through this yard.

TABLE 7.—*Effect of poor yard layout on length of time required to load 2-batch trucks*

Operation	Time in seconds
Closing end gates of truck	27.5
Driving to gravel bin and backing under	34.5
Loading gravel, 2 sizes, 2 batches	67.0
Driving to sand bin and backing under	44.0
Loading sand, 2 batches	30.0
Driving to cement car	39.5
Loading cement bags	57.5
Waits and delays	9.5
Total time required for taking on load	309.5

IF THE TIE WIRES ARE CUT AT THE LOADING PLATFORM TWO MEN CAN READILY EMPTY THE CEMENT BAGS ON THE BATCHES AT THE MIXER

EFFICIENT HANDLING OF CEMENT ELIMINATES DELAYS

Handling the cement bags sometimes consumes much more time than should be necessary. Twenty-five seconds per batch of seven bags is readily attained on many jobs, though some few of those studied consumed more than twice this much, usually because of improper loading platforms. For speedy loading, the platform should be somewhat higher than the top of the truck body. A little time will also be gained if the bags in the car are stacked to the same height as the number of bags required per batch.

On some jobs, especially in the more arid regions, a practice is made of hauling the sacks to the road on separate trucks and distributing them along the subgrade where they are later picked up by two or three men and emptied in the mixer skip. The records show that when the bags are properly and conveniently placed good laborers can empty them in the skip at the rate of 9 to 10 man-seconds per bag. About the same rate can be attained in dumping the cement bags on the trucks after they arrive at the mixer. Two men are usually employed for this work. The use of bulk cement is rapidly coming into vogue in some sections. Typical time studies of handling bulk cement in 2-wheel buggies show average values as given in Table 8.

The time which the trucks are necessarily delayed at the cement platform need only be a few seconds more than the time required to dump the buggies on the truck, or about 15 seconds per batch. At least one more buggy than the number of batches handled by each truck should be provided.

TABLE 8.—*Time of handling bulk cement; three men loading buggies*

Operation	Time in seconds
Loading buggy	67.0
Wheeling buggy to scales	13.0
Weighing and adjusting contents	16.4
Wheeling buggy to truck	7.2
Dumping buggy on truck	12.4
Returning buggy for loading	13.0
Total time per buggy	129.0

A few time studies have also been made on the operation of mechanical plants for handling bulk cement. The average values obtained from these studies are given in Table 9.

TABLE 9.—*Time of operation of bulk cement batcher*

Operation	Time in seconds
Loading and weighing	26.9
Dumping cement on truck	23.8
Total cycle	50.7

Present practice in handling bulk cement usually requires that the cement be dumped on top of the sand and gravel and a canvas cover be spread over the load or else that it be carried in a special container. Spreading and fastening down the canvas covering usually consumes from 20 to 30 seconds additional.

TRUCK OPERATION AT THE MIXER ANALYZED

When the truck reaches the vicinity of the mixer the first operation is usually to turn it either by maneuvering through a space where a couple of forms have been removed, or, more frequently, on a turntable. The value of the turntable lies chiefly in the fact that for some types of truck the time of turning is considerably decreased, and if the ground is soft the subgrade is not cut up so badly. Table 10 shows typical time studies of good operation of a light turntable in turning one-batch trucks.

A 3-BATCH TRUCK CAN BE TURNED ON A GOOD TURNTABLE IN LESS THAN ONE MINUTE

For heavy trucks a larger table is required, and the time elements are somewhat increased, but even a 3-batch truck can readily be turned in 60 seconds.

A rather common custom, where the cement is carried in bags on the batch-trucks, is to have the dumpers climb aboard as the truck reaches the turntable or the turning place. Two men can readily dump the bags

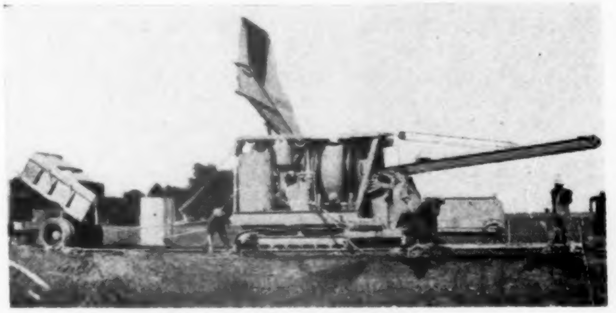
TABLE 10.—*Time analysis of turntable operation*

Operation	Time in seconds
Running truck on turntable	4.4
Rotating turntable 180°	12.1
Backing truck off turntable	7.7
Total time to turn truck	24.2
Time required to return turntable for use of next truck	10.6
Total operating cycle	34.8

while the truck is turning and backing to the mixer, especially if the tie wires are cut at the loading plant. More frequently a small platform or light truck is kept some distance ahead of the mixer, where each truck stops long enough for the men to step aboard, dump the bags, and step off. The time required is about 5 seconds per bag when two men work on the platform, or 10 man-seconds per bag. While this method makes it easier to take care of the empty bags, as they can all be saved, bundled, and tied up by the men who do the dumping, a definite amount is added to the time constant of the truck operation. For 2-batch trucks carrying 14 bags of cement this is seldom less than 75 seconds. The saving in bags and the added safety of the workers must then be balanced against this extra cost of truck time. Probably there are many jobs on which adoption of this method would prove profitable.

The operation of dumping the batch into the waiting skip usually presents no particularly time-consuming delays except where 1-batch trucks with gravity dump bodies are used. Some types of gravity dump body are very difficult to dump unless the load is placed exactly right, and especially so when the mixer is working down a steep grade. Needless to say, this type of dump body should never be permitted on the job. The actual dumping of properly equipped 1-batch trucks, as well as of each batch of the larger trucks, is often accomplished in 10 seconds, and in no case should the truck detain the skip for more than 30 seconds. An average time of 20 seconds for dropping each individual batch is found on many jobs. The total time which the truck is necessarily detained in unloading, however, varies with the number of batches carried and the operating cycle of the mixer. If the skip is down, the 1-batch truck can drop its batch and immediately proceed on its way for another load. The truck carrying two batches drops the first batch in the skip and immediately, without lowering the body, moves forward sufficiently to clear the skip, waits while the skip is raised and again returned to the ground, and then quickly backs up and drops the second batch. The total dumping time is therefore at least one full skip cycle (usually about 35 seconds) plus the time required to drop the two batches.

Ordinarily the mixer operator will not be ready to raise the skip as soon as the truck clears it after dumping the first batch. For 2-batch trucks, therefore, the total dumping time generally approximates 1¼ cycles on a well-managed job on which the practice is to have the truck bodies hoisted into dumping position before backing into the skip and to employ a dump man to drop the batches. The total dumping time of the 3 and 4 batch trucks, however, must include at least one or two full mixing cycles, respectively, plus one skip cycle and the time required to drop the first and the last batch. As in the case of the 2-batch truck, the time actually consumed in dropping the first and last batch will approximate 1½ cycles, so that the time the truck is actually detained even on perfect mixer and truck operation will closely approximate 2½ and 3½ mixer cycles for the 3 and 4 batch trucks, respectively. On the average job the total time the truck is detained at the mixer will be somewhat greater than this because of the delays to continuous mixer operation which occur from time to time, and the more batches carried the more frequently will these delays occur while the truck still has batches to unload rather than when trucks are being exchanged. This fact probably explains why the actual dumping time of the 3 and 4 batch trucks, as shown in Tables 3 and 4, is somewhat longer than would normally be expected when compared with the dumping time of the 2-batch trucks.



THE SECOND BATCH CAN BE DROPPED AS SOON AS THE SKIP IS LOWERED, BUT A FULL MIXER CYCLE MUST THEN ELAPSE BEFORE THE THIRD BATCH CAN BE DROPPED

HAULING SPEEDS VARY WITH LENGTH OF HAUL AND OTHER FACTORS

Practically all the stop-watch studies on truck operation show the time spent by each truck during each trip in driving from the loading yard to the turning point at the mixer, the time spent in returning from the mixer to the loading plant, and the exact mileage between these points. The condition of the road and the mechanical condition of the trucks is also noted. The road speed of both loaded and empty trucks is therefore readily obtained, as well as the average round-trip speed. The latter quantity should be computed by dividing twice the hauling distance by the total time, loaded and return. The average of the two speeds will not give the correct result, unless they are very nearly equal.

The variations in hauling speeds, both loaded and unloaded are very large. The studies made include jobs on which the average round-trip speed rarely exceeded 10 miles an hour and for individual 1-hour studies was as low as 6 miles an hour, as compared with jobs on which the average round-trip speed exceeded 30 miles an hour and exceeded 40 miles an hour during certain 1-hour studies. The speed was found to vary with many factors, the chief of which were grades, mechanical condition of the trucks, the type of trucks, the amount of traffic interference, whether or not all the trucks were capable of maintaining the same speed, the length of the haul, and particularly the condition of the road surface. The average length of haul from loading yard to mixer of 122 jobs was found to be 2.65 miles. Complete hauling studies are not available for all of these jobs, but the average round-trip speed on all those containing complete data was 18 miles an hour with maximum speeds on individual 1-hour studies running as high as 45 miles per hour to as low as 6.

Table 11, made up from the studies on four separate jobs, illustrates the great variations in average truck speed which are found in the field on different jobs and something of how the average round-trip speed on almost any job varies with the length of haul.

The records bring out three things quite clearly: First, that with good roads, proper equipment in good condition, freedom from traffic interference, and able management, fairly high hauling speeds can be maintained rather consistently; second, that with any one of these requirements lacking the uniform maintenance of high speeds is very difficult and probably impossible; and, third, that a high speed is ordinarily of little productive value unless it can be maintained fairly consistently and includes all the hauling units. Jobs using a variety of trucks of different sizes and speeds show almost without exception a low average speed and a large time constant.

The condition of the road also has a marked effect on the average round-trip speed which the hauling units can and do maintain. Table 12 shows the round-trip speed maintained by 1-batch trucks on an earth road which was generally in good condition, but became spongy and rutted after a rain.

Table 11.—*Data obtained from four fairly typical jobs, showing effect of length of haul on average round-trip speed*

Job No.	Hauling conditions	Length of haul	Average round-trip speed
		Miles	*Miles per hour*
1	Good pavement, 3-batch trucks, excellent condition	1.58	27.1
		1.81	27.5
		2.04	28.3
		4.35	33.7
		4.97	37.2
		6.24	40.2
2	Earth and gravel road, fair to poor; 2-batch trucks, fair condition	.18	6.0
		.46	10.9
		1.17	16.5
		1.73	17.4
3	Earth road, fair condition; 1-batch trucks, fair condition	.52	9.8
		.80	11.4
		1.02	13.1
		1.48	15.8
		1.87	16.5
		2.45	17.1
4	Earth, gravel and pavement, fair to poor; 3-batch trucks, fair condition	.66	7.2
		.95	8.1
		1.20	8.2
		1.78	8.7
		2.08	10.8
		2.30	10.4

Here →

Table 12.—*Effect of length of haul and road conditions on average round-trip speed; 1-batch trucks in good condition*

Condition of road	Length of haul	Average round-trip speed	Condition of road	Length of haul	Average round-trip speed
	Miles	*Miles per hour*		*Miles*	*Miles per hour*
Fair	0.35	10	Spongy, rutted	1.80	18
Do.	.55	14	Good	2.40	27
Good	.95	21	Fair	2.60	21
Spongy, rutted	1.15	15	Good	2.80	28
Good	1.45	24	Fair	2.90	24
Very good	1.65	31			

HAULING AND RETURNING SPEEDS DIFFERENT

The variation in speed between the loaded and the returning vehicle is sometimes very large. This is especially true on jobs using light 1-batch trucks for hauling a large size batch, thus overloading the trucks sufficiently to reduce materially the speed of the loaded vehicle. Trucks which are not overloaded do not show much variation between loaded and return speeds except when road conditions are poor. Table 13 gives the average hauling speeds on a selection of jobs most of which were operating under better than average conditions. It will be noted that the 1-batch trucks show the widest variations between hauling and returning speeds. This fact is definitely traceable to overloading of these light trucks.

Table 13.—*Effect of loading on speed of trucks in concrete paving work; selected jobs, road conditions good to fair*

Job No.	Number of batches per load	Average speed [1] Loaded	Average speed [1] Return	Job No.	Number of batches per load	Average speed [1] Loaded	Average speed [1] Return
		Miles per hour	*Miles per hour*			*Miles per hour*	*Miles per hour*
1	3	17.9	19.5	7	2	17.2	23.8
2	3	18.2	20.0	8	2	17.4	19.8
3	3	23.0	30.8	9	1	11.6	21.9
4	3	23.3	26.1	10	1	16.4	26.9
5	3	24.6	25.7	11	1	17.1	27.5
6	3	25.7	30.7				

[1] Averages of not less than 10 days.

A Few Planks to Bridge a Bad Place in the Road Sometimes Spell the Difference Between Capacity Production and a Complete Shutdown

FORMULA USED FOR ESTIMATING NUMBER OF TRUCKS REQUIRED

A survey of all these data indicates the difficulty of finding and applying any one standard rule or formula as a guide for the proper number of hauling units of any given kind which the contractor should put on his particular job and the manner in which this number should vary from day to day with the length of haul. The present investigation indicates that the only really valuable method is the regular use of the stop watch on the job to evaluate the various factors which make up the time constant and to obtain the actual round-trip speed; and then, by entering these values in a formula or a graph, to obtain the number of trucks which will be needed each following day. This method serves a double purpose: First, the time required to perform each operation under actual operating conditions becomes a matter of definite fact instead of opinion or guesswork; and, second, there is nothing on the job which equals the stop watch for discovering lost motion and wasted effort, and for finding means of improving operating methods. A good stop watch, with a little training in its use and in finding how the various operations should be timed, will undoubtedly prove to be of great value to any road contractor. In no other way can unnecessary time losses and faulty

methods of truck operation be so readily detected and the actual effect of new methods determined.

After the various time constants have been evaluated the following formula is suggested for finding the number of trucks needed. The chief merit of this equation lies, perhaps, in its form, which is such that its use should naturally stimulate an interest in each of the various factors which control the number of batches a given vehicle can deliver in a given time. The formula is perfectly general and can be applied to any set of hauling conditions in which the key equipment operates on some definite cycle. It is expressed as follows:

$$N=\frac{120L}{Snt}+\frac{T}{nt}$$

where N is the minimum number of trucks required to keep the mixer in continuous operation.

L is the length of haul in miles from the material yard to the mixer.

S is the average round-trip road speed, in miles per hour, maintained by the trucks between the above points.

T is the total time constant in minutes; i. e., the time which the truck is actually required to spend regularly in loading, turning, backing, dumping, and waiting during each round trip.

t is the actual mixer cycle in minutes; i. e., the time required to pass each batch through the mixer.

n is the number of batches carried by each truck.

The first term of this expression, $\frac{120L}{Snt}$, represents the number of trucks which under these operating conditions should be on the road at any moment, while the second term, $\frac{T}{nt}$, represents the number of trucks which should be either in the material yard or at the mixer.

NOMOGRAM USED TO FACILITATE SOLUTION

The alignment chart or nomogram shown in Figure 2 will frequently prove a timesaver in obtaining the number of trucks for any given set of conditions, and especially in making the numerous solutions required when it is desired to study the interrelated effects of the various factors such as speed, time constant, mixing cycle and the number of batches per load. The scales are logarithmic and equal, except for the middle scale, which is exactly one-half that of the others. The actual scales can therefore be picked off on a piece of drawing paper from an ordinary slide rule. The spacing of the vertical lines is immaterial except that line C should lie equidistant from lines A and E, and B and D, respectively. The vertical position of any two of the scales can be chosen arbitrarily and the position of the others then determined by a single solution of each part of the equation.

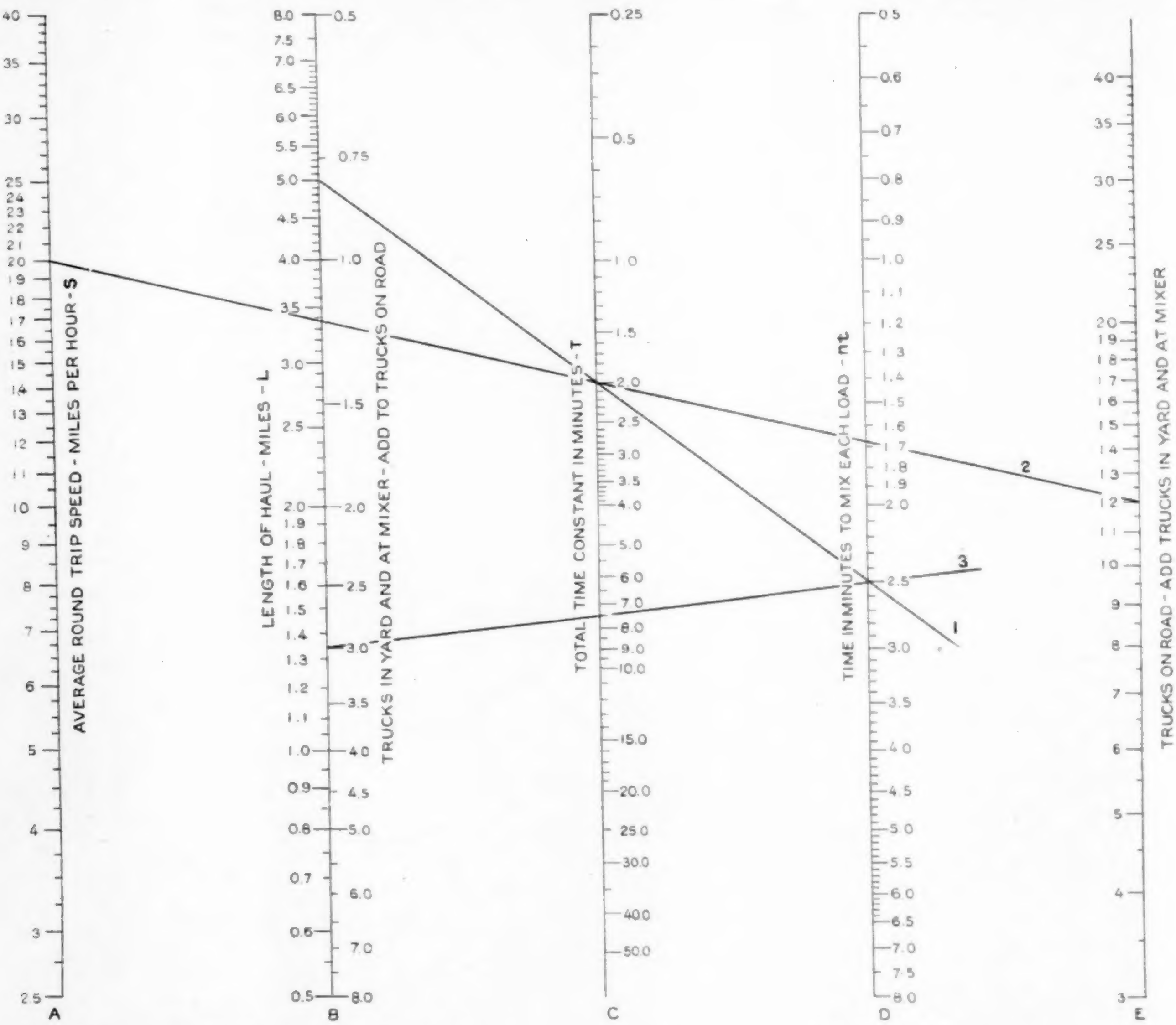
The method of solution is shown on the chart. Lines 1, 2, and 3 indicate the manner in which the straightedge is manipulated in the solution of the following problem: Required to find the number of 2-batch trucks capable of maintaining a round-trip speed of 20 miles per hour which are necessary to supply a mixer operating on a 75-second or 1¼-minute cycle when the haul is 5 miles and the total time constant, T, is 7.5 minutes. The number found is 12 plus 3, or a total of 15 two-batch trucks. It will be noted that in the solution of the first term the middle scale is used only to establish a point about which the straightedge is rotated.

The use of this chart or of the equation with the constants actually observed on various jobs is productive of much valuable information, as is shown by Table 14, which was computed in the following manner. The time constants found as average values on a number of very well managed jobs were used in computing, for various speeds and lengths of haul, the relative delivery ability of multiple-batch trucks in comparison with that of 1-batch trucks. In these computations the mixer was assumed to operate on a 75-second cycle. Computations were made for 1, 2, 3, and 4 batch trucks, for speeds varying from 10 to 40 miles per hour, and for hauls varying from one-fourth mile to 7 miles. For each set of conditions and for the time constants and mixer cycle as stated above, Table 14 gives the number of trucks required to keep the mixer in operation and the relative delivery value of the given type of truck, that of the 1-batch trucks being taken as 1.00 in all cases.

TABLE 14.—*Number of 1, 2, 3, and 4 batch trucks required to supply mixer and relative delivery value of each in terms of 1-batch trucks when operating under certain similar conditions as to speed and haul distance. Time constants equal 4.2, 8.0, 11.2, and 15.75 minutes for 1, 2, 3, and 4 batch trucks, respectively, mixer operating on a 75-second cycle*

Round-trip hauling speed (miles per hour)	Number of batches hauled per load		Length of haul in miles: ¼	½	1	2	3	4	5	6	7
10	1	Trucks [1]	5.8	8.2	13.0	22.6	32.2	41.8	51.4	61.0	70.6
		Value [2]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2	Trucks	4.4	5.6	8.0	12.8	17.6	22.4	27.2	32.0	36.8
		Values	1.32	1.46	1.63	1.77	1.83	1.87	1.89	1.90	1.92
	3	Trucks	3.8	4.6	6.2	9.4	12.6	15.8	19.0	22.2	25.4
		Value	1.52	1.78	2.10	2.40	2.55	2.65	2.70	2.74	2.77
	4	Trucks	3.7	4.3	5.5	7.9	10.3	12.7	15.1	17.5	19.9
		Value	1.57	1.91	2.37	2.86	3.13	3.29	3.41	3.48	3.54
15	1	Trucks	5.0	6.6	9.8	16.2	22.6	29.0	35.4	41.8	48.2
		Value	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2	Trucks	4.0	4.8	6.4	9.6	12.8	16.0	19.2	22.4	25.6
		Value	1.25	1.38	1.53	1.69	1.77	1.82	1.84	1.87	1.88
	3	Trucks	3.5	4.1	5.1	7.2	9.3	11.4	13.5	15.6	17.7
		Value	1.43	1.61	1.92	2.25	2.43	2.55	2.62	2.64	2.72
	4	Trucks	3.5	3.9	4.7	6.3	7.9	9.5	11.1	12.7	14.3
		Value	1.43	1.69	2.08	2.57	2.86	3.06	3.19	3.29	3.37
20	1	Trucks	4.6	5.8	8.2	13.0	17.8	22.6	27.4	32.2	37.0
		Value	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2	Trucks	3.8	4.4	5.6	8.0	10.4	12.8	15.2	17.6	20.0
		Value	1.21	1.32	1.46	1.63	1.71	1.77	1.80	1.83	1.85
	3	Trucks	3.4	3.8	4.6	6.2	7.8	9.4	11.0	12.6	14.2
		Value	1.35	1.52	1.78	2.10	2.28	2.40	2.49	2.55	2.61
	4	Trucks	3.4	3.7	4.3	5.5	6.7	7.9	9.1	10.3	11.5
		Value	1.35	1.57	1.91	2.37	2.66	2.86	3.01	3.13	3.22
25	1	Trucks	4.4	5.3	7.2	11.1	14.9	18.8	22.6	26.4	30.3
		Value	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2	Trucks	3.7	4.1	5.1	7.0	9.0	10.9	12.8	14.7	16.6
		Value	1.19	1.29	1.41	1.59	1.66	1.73	1.77	1.80	1.82
	3	Trucks	3.3	3.6	4.3	5.6	6.8	8.1	9.4	10.7	12.0
		Value	1.33	1.47	1.68	1.99	2.20	2.32	2.40	2.47	2.53
	4	Trucks	3.3	3.6	4.1	5.0	6.0	6.9	7.9	8.9	9.8
		Value	1.33	1.47	1.76	2.22	2.48	2.73	2.86	2.97	3.09
30	1	Trucks	4.2	5.0	6.6	9.8	13.0	16.2	19.4	22.6	25.8
		Value	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2	Trucks	3.6	4.0	4.8	6.4	8.0	9.6	11.2	12.8	14.4
		Value	1.17	1.25	1.38	1.53	1.63	1.69	1.73	1.77	1.79
	3	Trucks	3.3	3.5	4.1	5.1	6.2	7.3	8.4	9.4	10.5
		Value	1.27	1.43	1.61	1.92	2.10	2.24	2.31	2.40	2.46
	4	Trucks	3.3	3.5	3.9	4.7	5.5	6.3	7.1	7.9	8.9
		Value	1.27	1.43	1.69	2.08	2.37	2.57	2.74	2.86	2.97
40	1	Trucks	4.0	4.6	5.8	8.2	10.6	13.0	15.4	17.8	20.2
		Value	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2	Trucks	3.5	3.8	4.4	5.6	6.8	8.0	9.2	10.4	11.6
		Value	1.15	1.21	1.32	1.46	1.56	1.63	1.68	1.71	1.74
	3	Trucks	3.2	3.4	3.8	4.6	5.4	6.2	7.0	7.8	8.6
		Value	1.25	1.35	1.52	1.78	1.97	2.10	2.20	2.28	2.35
	4	Trucks	3.2	3.4	3.7	4.3	4.9	5.5	6.1	6.7	7.3
		Value	1.25	1.35	1.57	1.91	2.16	2.37	2.53	2.66	2.77

[1] Number of trucks required.
[2] Relative delivery value. That of a 1-batch truck is taken in all cases as 1.00.



FORMULA FOR COMPUTING NUMBER OF TRUCKS REQUIRED

$N = \frac{120L}{snt} + \frac{T}{nt}$

L = HAUL IN MILES
S = ROUND-TRIP SPEED IN MILES
T = TOTAL TIME CONSTANT IN MINUTES
t = MIXER CYCLE IN MINUTES
n = NUMBER OF BATCHES PER TRUCK
N = NUMBER OF TRUCKS REQUIRED

PROCEDURE

TO OBTAIN FIRST TERM OF FORMULA, PLACE STRAIGHTEDGE TO INTERSECT LINES B AND D AT PROPER SCALE VALUES OF L AND nt, RESPECTIVELY, AND MARK INTERSECTION WITH LINE C; ROTATE STRAIGHTEDGE ABOUT THIS INTERSECTION TO INTERSECT LINE A AT PROPER SCALE VALUE OF S; READ QUOTIENT $\frac{120L}{snt}$, ON LINE E. TO OBTAIN SECOND TERM OF FORMULA, PLACE STRAIGHTEDGE TO INTERSECT LINES C AND D AT PROPER SCALE VALUES OF T AND nt RESPECTIVELY; READ QUOTIENT $\frac{T}{nt}$, ON RIGHT HAND SCALE OF LINE B. ADD THESE TWO QUOTIENTS TO OBTAIN N

FIGURE 2.—NOMOGRAM FOR COMPUTING NUMBER OF TRUCKS REQUIRED FOR GIVEN CONDITIONS OF HAUL AND MIXER OPERATION

LARGE TRUCKS AT DISADVANTAGE ON SHORT HAULS

This table, which is based on the average time constants found on well-managed jobs, seems to indicate that for much of our short-haul paving work the large trucks operate under a rather serious handicap. Thus, on a ¼-mile haul and a round-trip speed of 10 miles an hour, which is quite common on hauls of this length, a 4-batch truck is only worth, in delivering batches, about 57 per cent more per hour than a 1-batch truck, and only about 19 per cent more than a 2-batch truck. Even on a ½-mile haul and at an average round-trip speed of 15 miles per hour, the 4-batch truck is worth in delivering batches only about 69 per cent more than the 1-batch truck and only about 22 per cent more than a 2-batch truck, which of itself is worth only about 38 per cent more than the 1-batch truck. When the haul has reached an average of about 1 mile, the round-trip speed should be about 20 miles per hour. In this case the 2-batch truck becomes nearly equal in delivery value to 1.5 one-batch trucks, and the 4-batch truck nearly equal to 2 one-batch trucks, or to 1.3 two-batch trucks. On long hauls the apparent advantage of the 1-batch truck at even equal speeds practically disappears.

It should not be inferred from these results that one particular size of truck is necessarily more economical

or more desirable for concrete paving work than any other on a given job. The relative cost of hiring or operating the various sizes of trucks must also be considered. For example, on a haul of 1 mile, with an average round-trip speed of 20 miles per hour, and time constants the same as those used in computing Table 14, all trucks would be equally desirable from a cost standpoint if they could be either hired or operated at the following total costs per hour; 1-batch at $1, 2-batch at $1.46, 3-batch at $1.78, and 4-batch at $1.91 per hour, or at any other hourly costs which would maintain this ratio. Similar equality would be attained under the same hauling conditions on a 4-mile haul when the rental or total operating costs of the trucks were as follows: 1-batch, $1; 2-batch, $1.77; 3-batch, $2.40; and 4-batch, $2.86 per hour. These comparisons are based on the assumption that all the trucks maintain the same round-trip speed. If the speeds are different the table can still be used for finding the relative delivery value of any two or more trucks. Thus, if the constants are as above except that the 1-batch trucks can only maintain a round-trip speed of 15 miles per hour as compared with 30 miles per hour for a 2-batch truck, then a 1-mile haul would require ten 1-batch trucks or five 2-batch trucks in order to keep the mixer fully supplied. Under these conditions the delivery value of a 2-batch truck would be equal to that of two 1-batch trucks. Consequently, if 1-batch trucks cost $1 per hour, the 2-batch trucks would be worth $2 per hour in hauling batches to the mixer.

Different values of the time constants, T, will naturally modify the values given in Table 14, and in every case the contractor should use the stop watch to determine both the time constants and the speeds at which he can operate under his own conditions, and should recheck these values from time to time. He will then have definite facts on which to determine both the number of trucks required from day to day and the size of trucks which will be most advantageous for his particular requirements.

DISADVANTAGES OF CONTRACT HAULING DISCUSSED

That degree of coordination which must be maintained between the mixer and the hauling equipment with respect to both supply and operation, in order to produce square yards of pavement in place at the lowest possible unit operating cost, can only be achieved if all the operations involved are under the full control of one party. The rather general practice of subcontracting the batch hauling not only divides authority but it sets up two parties with essentially opposing interests, one of which must be subordinated if the job as a whole is to be operated on the most economical plan.

It has been noted that the operating time of the mixer is worth about 75 cents a minute. The time of a truck is ordinarily worth from 2 to 5 cents a minute, depending on the size and type of the vehicle. For both the mixer and the trucks the cost is very nearly constant so long as they are at work, regardless of whether production is high or low. Consequently both the paving contractor and the hauling contractor endeavor to keep their own equipment in steady operation. But the mixer can not operate continuously unless there is an equally steady supply of batches at the skip, and it has been shown that 100 per cent mixer operation over long periods is practically impossible. This means that the rate of demand of the mixer fluctuates; in order to provide for these fluctuations there must be a certain oversupply of trucks. If the paving contractor can eliminate two minutes of lost mixer time per hour by hiring another 1-batch truck he will ordinarily be ahead financially. To the hauling contractor, on the other hand, the provision of this extra truck will mean almost certain loss, since the total waiting time of the trucks will be increased. The usual form of batch-hauling contract calls for compensation on the basis of batch-mile or similar unit. For this reason the hauling contract can be completed at the lowest cost only when no more trucks are employed than can always operate freely without having to wait at the mixer. Nor is there usually any increase in the actual cost of the hauling if the number of trucks is decreased far below that actually required to maintain the rate of the mixer. There is, therefore, no economic incentive for the hauling contractor to have even a full supply of trucks.

Nor is there any great inducement for him to eliminate faulty truck operation which gives rise to delays at the mixer. A minute lost in waiting for the truck to be properly squared around to dump its batch means a definite loss of about 75 cents to the main contractor, but to the hauling contractor the loss will probably not be more than 2 cents if the vehicle is a 1-batch truck, or more than 5 cents in any case. Furthermore, the delays which arise from various forms of inefficiency in truck operation are about four times as large as those which arise from an inadequate supply. Contract hauling, therefore, involves financial risks to the main contractor which should not be assumed without very definite and certain compensating advantages.

These facts indicate clearly that full authority over both truck supply and truck operation should be placed in the hands of the main contractor if the lowest possible cost of producing concrete pavement is to be attained. He is the only one who very materially benefits from efficient truck operation, or who can properly gauge the loss due to an oversupply of trucks as compard with the added insurance which they provide against the more expensive mixer delays. The most desirable amount of truck oversupply will, no doubt, vary from job to job, but so long as mixer delays are caused by truck shortages and the ratio of the value of truck time to mixer time may be as great as 1 to 35, a certain amount will be advisable. For the contractor to own sufficient trucks to supply the longest occasional haul would probably be unprofitable, unless other uses should be available for the extra trucks after completion of the long haul.

In view of the fact that the average haul for all jobs studied in this analysis was 2.65 miles, it would not seem advisable for the ordinary contractor to keep on hand haulding equipment sufficient to supply the full requirements of the mixer on hauls of more than about 3 miles. Under ordinary operating conditions an average round-trip speed of 20 miles per hour, and a 1-minute mixing specification, a 3-mile haul would require about 18 one-batch, 11 two-batch, 8 three-batch, or 7 four-batch brucks. On the first part of a 6-mile haul (assuming no increase in average speed) this plan would involve the hiring of 3 four-batch, 5 three-batch, 7 two-batch, or 14 one-batch trucks, each hired truck to be released when no longer required. In order to insure getting these extra trucks when needed and maintaining full authority over the control of the drivers, it would probably be necessary to pay a little above the prevailing rental, but this item should not equal the carrying

(Continued on page 260)

HIGH-SPEED PRODUCTION ON ASPHALT CONCRETE PAVING WORK

Reported by R. W. Edwards and N. L. James, Junior Highway Engineers, U. S. Bureau of Public Roads

AN UNUSUAL rate of production in asphalt paving work was maintained on California Federal-aid Project No. 194-A, during the construction season of 1930. On this project, which is situated south of Fresno, Calif., between Malaga and Fowler, and south of the latter, 43,556 tons of asphalt concrete were laid over a distance of 7.54 miles, between August 18 and October 8. The average production for each 8-hour operating day was 1,050 tons. The maximum for any one day was 1,204 tons. The company which did this work has carried its production efficiency to increasingly high standards during the last year. On two previous jobs, at Salinas, Calif., and at Tulare, average production rates of 802 tons and 927 tons, respectively, were established.

That this high rate of production was largely due to efficient management is demonstrated by the results of production studies conducted on this project by the United States Bureau of Public Roads. A scientifically designed asphalt plant of large capacity was selected for the work, together with auxiliary equipment capable of keeping pace with it. Labor and directing personnel were efficient and well paid. Studies of time and production losses on previous jobs enabled the contractors to eliminate such losses on this project. The production studies show that the total loss of available operating time was less than 10 per cent, while the time lost with the crew on the job was less than 3 per cent.

ASPHALT CONCRETE SURFACE LAID ON OLD PORTLAND CEMENT CONCRETE PAVEMENT

The entire 7.54 miles of asphalt concrete surface was laid on an old Portland cement pavement, with the exception of a few changes of alignment which required construction over a new subgrade. For a distance of 4.69 miles, between Malaga and Fowler, the asphalt concrete was laid to a width of 30 feet. The remaining 2.85 miles, lying south of Fowler, is 20 feet wide. The new pavement was constructed in three courses, a base or primary leveling course, used to fill in shoulders, etc., a leveling course, and a surface course. The latter is normally 2 inches thick, while the thickness of the other courses varies considerably. The total thickness of the pavement varies from 9 inches at the edges to about 3 inches at the center, depending upon the irregularities of the old pavement.

PAVING COMPLETED IN 41½ WORKING DAYS

The contract was awarded on July 16, 1930, and the work of clearing and grubbing and providing material for grading the roadbed for the new construction was begun on July 17. Work on culverts and small structures was begun on July 21. Erection of the asphalt plant was begun at Malaga on July 16. The plant erection was completed on August 15, and other preliminary work was sufficiently advanced or completed to permit asphalt paving to start on Monday, August 18. The paving was in progress from August 18 to noon of October 8, a total period of 51½ calendar days including 7 Sundays, Labor Day, and one Mexican holiday. This resulted in 42½ available working days, and out of this one day was lost due to rain or wet grade. The daily average was 1,049.5 tons per actual working day and 1,023.4 tons per available day.

The price received for the asphalt concrete was $4.01 per ton. This price covered all items from furnishing and setting permanent wooden forms to finishing and rolling the pavement. The total for 43,556 tons was approximately $174,660, or $23,164 per mile. The cost per square yard was approximately $1.50.

The general superintendent for the paving company had complete charge of the entire contract and the superintendent of plants was in charge of plant operations. There was a capable foreman for each division of the work, such as hauling, spreading and finishing, setting forms, etc. Two experienced timekeepers were employed to take care of the clerical work and to attend to the ordering of all materials and supplies. These timekeepers enabled the superintendent to devote his entire time to planning and supervision. A carefully planned and detailed schedule of operations was prepared at the start of the job and as a result no delays whatever occurred due to lack of planning or to inefficient management. It was the duty of each foreman to see that his equipment and personnel functioned efficiently and to correct delays immediately. It was through this specialization on the part of the men and coordination on the part of the general superintendent that this job proceeded so smoothly and at such a remarkable rate.

The normal crew per working shift averaged 62 men, which included 16 at the plant, 8 hauling materials to the job, 17 handling material on the job, including rolling, etc., 12 form setters, and 9 on supervision and miscellaneous work.

ADEQUATE MODERN EQUIPMENT USED

The major items of equipment were:

- 1 new, all-steel, portable asphalt plant, consisting of a 4,000-pound, 80 r. p. m. pug-mill and a 6-foot by 22-foot 8 r. p. m. dryer.
- 1 1¼ cubic yard clamshell crane (feeding plant).
- 10 trucks hauling 3 batches or 6.3 tons.
- 3 9-foot spreader boxes.
- 1 30-foot finishing machine.
- 1 20-foot finishing machine.
- 1 10-ton, 3 wheel gas roller.
- 3 8-ton tandem rollers.
- 1 water-tank truck.
- 4 runabout passenger cars.
- 1 blacksmith shop.
- 1 portable field office.

All of the above equipment was of the latest design and in first-class condition.

HANDLING OF MATERIALS DISCUSSED

Materials other than sand were delivered by rail to the plant, located on a siding at Malaga, near the north end of the project. Sand was produced locally and hauled to the plant by subcontract from pits about 8 miles distant. One pit supplied course sand and the other fine sand. It was necessary to premix or blend these sands at the plant to obtain the grading required in the specifications.

The aggregates were unloaded from the cars by the 1¼-yard clamshell crane and either stock-piled or fed into the hoppers at the cold elevator. There were three of these hoppers; one was used for the sand and No. 4 rock, the latter varying from 1¼ to ¾ inch in size. A second hopper was used for No. 3 rock, varying from ¾-inch to rock retained on a No. 3 screen, and a third for No. 2 rock, which was such as to pass a No. 3 screen and be retained on a No. 10 screen. The sand used was such as to pass a No. 10 screen, and included some finer than that retained on a No. 200 screen. Three adjustable gates, regulated by a feeder operator, admitted each size of material to the boot or hopper of the cold elevator. It is interesting to note that each of these materials arrived at the plant in precisely the grading desired in the four hot-storage bins. This was the chief reason for the exceptionally small percentage of bin delays or delays due to lack of proper size of hot aggregate.

Materials after leaving the stock piles passed through the dryer where they were heated to 375° or 400°. They were then conveyed by a bucket elevator to the screens where they were screened and chuted into four hot-storage bins, each bin containing a certain size. All aggregates passed the 1¼-inch screen except part of that for the base course, where a maximum size of 2 inches was used.

Passing from the hot-storage bins, materials were batched by weight in the weigh box, which was suspended on multiple-beam scales, so that each size could be weighed rapidly and accurately. Dust was conveyed from a dust hopper to the weigh box by means of a mechanically driven screw operated by the batcher operator, and weighed on the multiple-beam scales. The dust was not heated. After the materials were weighed, they were dumped into the mixer box by the mixer operator. The gate of the weigh box opened at right angles to the mixer shafts; this arrangement facilitated even distribution of the materials in the mixer. Baffle plates were installed in the weigh box to distribute the materials issuing from the four hot-storage boxes. In order still further to assure even distribution, a definite sequence was adopted for weighing each material.

Asphalt cement, heated to about 280° was weighed and admitted to the mixer, parallel to the mixer shafts, by another operator, who also discharged the mixer and dumped the truck hopper or "gob" box. The mixer gate and truck hopper were operated by steam pistons, controlled by steam valves.

HAULING OPERATION CAREFULLY TIMED

The asphalt concrete, after being weighed by the State highway authorities, was hauled to the job in trucks equipped with tarpaulins. All trucks hauled three batches or 6.3 tons, and all trucks were pneumatic tired. Truck speeds averaged 22 miles per hour. The trucks were turned about 200 feet ahead of the finishing machine and were backed and hooked to the spreader boxes. The contents of each were then dumped on the street ahead of the finishing machine to approximately the desired depth. The terminal time constants of operation for these trucks averaged 6.5 minutes per trip. A careful scrutiny of the time of arrival and departure of trucks from the plant was made by the company to check upon the efficiency of truck operation.

FINISHING MACHINES USED FOR PAVING

A finishing machine was employed to spread the material and strike it off to the desired section. For the 30-foot section a rebuilt machine was used. For the 20-foot section a regular finishing machine, partly rebuilt and speeded up, was used. Studies disclosed that the 30-foot machine would travel at the rate of 7.8 feet per minute and would handle approximately 194 tons per hour, while the 20-foot machine would travel 12.6 feet per minute and handle 205 tons per hour.

Compaction was obtained by the use of four rollers, one 10-ton, 3-wheel roller and three 8-ton tandems. The 10-ton and one 8-ton roller were used for longitudinal rolling and the other two 8-ton rollers were used for transverse or crescent rolling. Late in the afternoon two of the 8-ton tandem rollers were used to roll out bumps.

PRODUCTION STUDIES COVERED BOTH PLANT AND AUXILIARY EQUIPMENT

The studies conducted on this project by the engineers of the Bureau of Public Roads covered the period from September 15 to October 8, and included the following major items:

1. Making several stop-watch studies every day of the operation of the asphalt plant. The purpose of these studies was to determine the amounts and sources of delays at the mixer.
2. Making daily stop-watch studies of auxiliary equipment to determine their rates of production, and to ascertain whether or not they favored or limited the attainment of maximum production by the asphalt plant.

A number of other features of the construction were also studied, including mixing time tests to determine the effect of the length of mixing time on the distribution of aggregates and asphalt in the mixer.

In order that the mixing operation might be carefully controlled during the period when time studies were being made, a timing device was installed on September 3. Although it was an innovation in asphalt work, the use of this device resulted in an almost clocklike regularity of plant operation, a nearly constant mixing time, and approximately a 6.5 per cent increase in rate of production.

For the purpose of the production study, the charging time was taken as the total time consumed in emptying all ingredients into the pugmill. The mixing time was taken as the interval between the completion of the charging and the opening of the discharge gate. The discharge time was taken as the time from the opening of the gate to the completion of discharge. A summary of the results of the plant production study is given in Table 1. It will be observed that for the base and leveling courses the possible number of batches per hour proved to be 73, while for the surface course 61.2 batches were found to be possible. Minor delays brought these rates down to 69.8 and 60.6 actual batches per hour, respectively. These figures are practically the same as the maximum production rates allowed by the State

authorities, who would suspend plant operation if production exceeded 70 batches per hour for the base and leveling courses and 60 batches per hour for the surface course. The reason for the difference between the number of batches allowed for base or leveling course and surface course was the fact that the State required a "double charge" on the surface materials, i. e., No. 3 stone was weighed separately and after the weighing and dumping of the other aggregates.

TABLE 1.—*Production data for period of study, September 15 to October 8, 1930*

Item	Base and leveling courses	Surface course and screenings
Charging time, seconds	6.8	15.7
Mixing time, seconds	28.3	27.9
Discharge time, seconds	14.2	15.2
Total cycle, seconds	49.3	58.8
Net batches possible per hour	73.0	61.2
Per cent of hour lost in minor delays	4.45	0.78
Per cent of hour utilized	95.55	99.22
Actual batches per hour	69.8	60.6
Actual tons per hour of operation	152.0	131.0
Average tons per day on days operated	[1] 1,066.9	
Average haul to job, miles	5.57	
Average number trucks for both courses	15.2	
Actual job efficiency including unavoidable delays	90.41	
Actual job efficiency excluding unavoidable delays	97.14	

[1] All courses.

TABLE 2.—*Production data for entire paving period, August 18 to October 8, 1930*

Item	Base and leveling courses	Surface course and screenings	Entire job
Total hours mixing time	208.80	108.25	317.05
Total tons mixed	29,823.05	13,732.91	43,555.96
Total batches mixed	13,548	6,373	19,921
Average tons per batch	2.20	2.15	2.19
Actual batches per hour	64.89	58.87	62.86
Actual tons per hour	142.83	126.85	137.38
Average tons per day on days available			1,024.85
Average tons per day on actual working days			1,049.50

The production data for the entire paving period are given in Table 2. It will be noted that the actual number of batches per hour was considerably less for the entire job than for the period from September 15 to October 8, when the timing device was in operation.

DELAYS IN PRODUCTION ANALYZED

In Table 3 is given an analysis of the delays occurring during the entire paving period. Time losses are grouped into two divisions, major and minor. Major delays are those 15 minutes or more in length and minor delays are those less than 15 minutes in length. Minor delays usually occur much more frequently than major delays and generally far exceed the major delays in total time even though each may be less than a minute in length. These minor delays are usually the most serious consumers of profits. Major delays fall into two classes: Those occurring with the full crew on the job and those occurring with the major portion of the crew laid off. Delays are classified as avoidable or unavoidable, and the efficiency of the organization is computed exclusive of the unavoidable delays. It is particularly interesting to note that on this project the major delays were all unavoidable and exceeded the minor delays which are believed to be mostly avoidable. The cost and difficulty of further reducing these minor delays would have been great and it is questionable if it could have been done. To illustrate clearly the cost of these time losses, they are evaluated

TABLE 3.—*Analysis of delays during entire paving period, August 18 to October 8, 1930. Total available working days during period, 42.50; total available hours, 340.50*

Item	Delay in hours	Per cent of total available time	Estimated cost
Major delays—unavoidable:			
Handling on grade	1.66	0.49	$197.81
Crane repairs	.50	.15	59.59
Plant equipment repairs	4.62	1.36	550.61
Lack of asphalt	.75	.22	89.39
Power off	.25	.07	29.80
Electrical repairs	1.17	.34	139.44
Rain or wet grade (crew off job)	14.50	4.25	302.04
Total	23.45	6.88	1,368.71
Minor delays—probably avoidable:			
Truck operation	.22	.06	26.22
Lack of hot materials	3.14	.92	374.23
Operative delays	2.31	.68	275.31
Handling on grade	4.05	1.19	482.68
Total	9.72	2.85	1,158.44
Grand total, all delays	33.17	9.73	2,527.15

at the rate of $119.18 per hour, which is a conservative value for the normal personnel and organization employed, and the estimated cost is given in Table 3. It should be noted that for the periods when the crew was not on the job the estimated cost of delay was not computed on this basis.

(Continued from page 257)

cost of owning these vehicles during the long periods when they would not be needed on the job.

That both owned and hired hauling units can be combined and operated at a high degree of efficiency when full control is maintained over the hired units is amply demonstrated on several jobs included in this study. On one of these jobs, using partly owned and partly hired hauling units, a rate of over 50 batches an hour was attained during several weeks with a time loss of less than one-half of 1 per cent from faulty truck operation on a haul which at one time exceeded 8 miles. The mixing time was 50 seconds.

CONCLUSIONS OF INVESTIGATION SUMMARIZED

The major point brought out in this investigation is the fact that under present methods and practices of providing, directing and operating the hauling equipment, the paving contractor loses about 17 per cent of his time, which might otherwise be utilized in further production. A part of this loss is due to the rather prevalent use of a method of subcontracting in which the economic interests of the two parties are antagonistic. The use of this system, at least in its present form, is unsatisfactory and should be discontinued. A larger portion of these time losess, however, are due to faulty or inefficient operation. Numerous instances are found where under able management and proper supervision these time losses have been greatly reduced and a corresponding financial reward obtained. Too frequently much of the seeming inefficiency of the truck operation is really due to a poor yard layout or to faulty operation of the loading equipment. Careful planning of the yard layout before the loading plant is set up should obviate many of these difficulties. Once the work of pouring concrete has actually begun, nothing will probably prove so effective in reducing time losses and correcting faulty methods of operation as able supervision abundantly supplied with actual facts obtained through frequent use of the stop watch.

ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS

Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.

ANNUAL REPORTS

Report of the Chief of the Bureau of Public Roads, 1924.
Report of the Chief of the Bureau of Public Roads, 1925.
Report of the Chief of the Bureau of Public Roads, 1927.
Report of the Chief of the Bureau of Public Roads, 1928.
Report of the Chief of the Bureau of Public Roads, 1929.
Report of the Chief of the Bureau of Public Roads, 1930.

DEPARTMENT BULLETINS

No. *136D. Highway Bonds. 20c.

*314D. Methods for the Examination of Bituminous Road Materials. 10c.

*347D. Methods for the Determination of the Physical Properties of Road-Building Rock. 10c.

*532D. The Expansion and Contraction of Concrete and Concrete Roads. 10c.

*583D. Reports on Experimental Convict Road Camp, Fulton County, Ga. 25c.

*660D. Highway Cost Keeping. 10c.

*691D. Typical Specifications for Bituminous Road Materials. 10c.

1216D. Tentative Standard Methods of Sampling and Testing Highway Materials, adopted by the American Association of State Highway Officials and approved by the Secretary of Agriculture for use in connection with Federal-aid road construction.

1279D. Rural Highway Mileage, Income, and Expenditures 1921 and 1922.

1486D. Highway Bridge Location.

DEPARTMENT CIRCULARS

No. 331C. Standard Specifications for Corrugated Metal Pipe Culverts.

TECHNICAL BULLETIN

No. 55T. Highway Bridge Surveys.

MISCELLANEOUS CIRCULARS

No. 62M. Standards Governing Plans, Specifications, Contract Forms, and Estimates for Federal-Aid Highway Projects.

*93M. Direct Production Costs of Broken Stone. 25c.

109M. Federal Legislation and Regulations Relating to the Improvement of Federal-Aid Roads and National Forest Roads and Trails, Flood Relief, and Miscellaneous Matters.

MISCELLANEOUS PUBLICATIONS

No. 76MP. The Results of Physical Tests of Road-Building Rock.

SEPARATE REPRINTS FROM THE YEARBOOK

No. *914Y. Highways and Highway Transportation. 25c.

937Y. Miscellaneous Agricultural Statistics.

1036Y. Road Work on Farm Outlets Needs Skill and Right Equipment.

TRANSPORTATION SURVEY REPORTS

Report of a Survey of Transportation on the State Highway System of Ohio. (1927)

Report of a Survey of Transportation on the State Highways of Vermont. (1927)

Report of a Survey of Transportation on the State Highways of New Hampshire. (1927)

Report of a Plan of Highway Improvement in the Regional Area of Cleveland, Ohio. (1928)

Report of a Survey of Transportation on the State Highways of Pennsylvania. (1928)

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH

Vol. 5, No. 17, D- 2. Effect of Controllable Variables upon the Penetration Test for Asphalts and Asphalt Cements.

Vol. 5, No. 19, D- 3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.

Vol. 5, No. 24, D- 6. A New Penetration Needle for Use in Testing Bituminous Materials.

Vol. 6, No. 6, D- 8. Tests of Three Large-Sized Reinforced-Concrete Slabs Under Concentrated Loading.

Vol. 11, No. 10, D-15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.

*Department supply exhausted.

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

CURRENT STATUS OF FEDERAL AID ROAD CONSTRUCTION

AS OF

JANUARY 31, 1931

STATE	COMPLETED MILEAGE	UNDER CONSTRUCTION					APPROVED FOR CONSTRUCTION					BALANCE OF FEDERAL-AID FUNDS AVAILABLE FOR NEW PROJECTS	STATE
		Estimated total cost	Federal aid allotted	MILEAGE			Estimated total cost	Federal aid allotted	MILEAGE				
				Initial	Stage[1]	Total			Initial	Stage[1]	Total		
Alabama	2,177.5	$ 5,219,430.13	$ 2,492,546.80	192.4	27.3	219.7	$ 702,983.97	$ 350,664.72	25.5	3.6	29.1	$ 4,724,072.45	Alabama
Arizona	897.1	3,590,078.21	2,793,599.38	122.0	152.4	274.4	705,392.22	527,811.20	30.9	10.9	41.8	1,852,068.18	Arizona
Arkansas	1,841.1	4,964,099.03	2,304,510.97	161.0	34.7	195.7	1,011,923.15	500,133.55	15.8	13.5	29.3	2,809,350.25	Arkansas
California	1,958.6	7,275,115.23	3,216,368.74	166.2	25.0	191.2	1,696,620.59	791,289.47	39.9	5.9	45.8	3,753,499.51	California
Colorado	1,297.0	3,499,857.27	1,861,936.92	126.0	57.9	183.9	1,346,024.23	755,307.11	64.8	32.5	97.3	3,443,256.71	Colorado
Connecticut	258.2	1,524,709.41	661,789.48	7.6		7.6	1,901,918.93	659,661.99	24.2		24.2	661,956.08	Connecticut
Delaware	318.9	106,632.85	53,316.42	4.4		4.4	434,115.60	216,303.30	12.9		12.9	434,889.13	Delaware
Florida	521.2	5,062,660.24	2,404,264.34	98.6	5.5	104.1	534,834.24	253,166.16	17.6		17.6	2,530,423.87	Florida
Georgia	2,679.7	7,491,514.03	3,576,755.42	199.1	126.1	325.2	2,516,247.57	1,138,060.05	40.9	51.4	92.3	3,605,442.97	Georgia
Idaho	1,296.1	2,124,358.93	1,292,251.73	151.3	12.5	163.8	765,555.18	462,016.46	55.8	7.2	63.0	1,515,888.19	Idaho
Illinois	2,183.4	19,997,552.33	9,092,122.16	571.4	57.3	628.7	1,357,755.68	845,586.15	47.6		47.6	7,133,268.00	Illinois
Indiana	1,579.0	2,090,716.05	1,012,682.46	65.4		65.4	4,835,824.97	1,799,739.32	103.7		103.7	3,897,752.34	Indiana
Iowa	3,229.0	105,290.11	1,892.77		4.1	4.1	7,433,114.40	3,113,633.23	157.9	77.6	235.5	237,794.44	Iowa
Kansas	2,984.9	5,154,094.19	2,434,386.56	276.4	29.6	306.0	2,805,058.09	1,269,270.46	221.8	40.7	262.5	2,840,918.46	Kansas
Kentucky	1,539.6	5,157,002.60	2,317,944.43	176.8	74.0	250.8	2,145,559.83	393,870.13	28.1	22.0	50.1	1,531,097.32	Kentucky
Louisiana	1,427.4	4,312,239.69	2,128,156.36	176.2	8.3	184.5	4,037,806.36	1,786,228.72	86.5	12.7	99.2	812,282.55	Louisiana
Maine	589.1	2,038,579.09	673,182.41	45.8		45.8	972,605.32	375,524.35	7.4		7.4	1,813,909.20	Maine
Maryland	693.1	646,177.07	297,189.33	6.4	7.3	13.7	291,945.10	108,661.80	4.9	2.4	7.3	932,619.59	Maryland
Massachusetts	711.8	8,271,609.92	2,125,108.27	73.3		73.3	381,271.27	56,400.00	3.8		3.8	2,469,043.29	Massachusetts
Michigan	1,788.3	7,867,016.97	3,297,669.03	205.4	22.9	228.3	1,678,095.94	627,937.17	37.5	12.8	50.3	4,018,208.09	Michigan
Minnesota	4,317.4	2,041,829.15	768,564.13	22.3	92.9	115.2	5,151,384.65	1,987,745.64	54.6	159.3	213.9	980,922.68	Minnesota
Mississippi	1,816.5	1,034,435.33	513,527.80	35.6	31.4	67.0	459,787.66	229,893.82	11.1	21.1	32.2	5,273,159.91	Mississippi
Missouri	2,596.2	8,426,700.96	3,019,508.08	146.2	49.8	196.0	2,948,063.16	1,332,209.13	103.1	26.0	129.1	2,214,961.53	Missouri
Montana	1,892.0	7,343,731.48	4,144,714.08	573.6	40.9	614.5	2,166,732.30	1,211,963.59	156.8	26.4	183.2	4,098,860.13	Montana
Nebraska	3,862.9	4,754,108.56	2,290,677.26	268.3	69.8	338.1	1,572,253.53	669,379.65	45.1	22.8	67.9	3,649,467.21	Nebraska
Nevada	1,278.0	1,005,734.41	871,720.23	52.4	63.4	115.8	10,142.81	9,011.88		.8	.8	1,881,583.08	Nevada
New Hampshire	392.1	595,296.53	222,027.15	9.6		9.6						672,[illegible]96.18	New Hampshire
New Jersey	554.9	2,855,418.71	768,991.32	19.6		19.6	822,104.55	350,793.09	12.8		12.8	2,197,618.67	New Jersey
New Mexico	2,008.6	3,470,620.18	2,298,222.40	138.7	40.5	179.2	966,711.60	672,586.97	30.7		30.7	1,959,479.03	New Mexico
New York	2,676.8	16,432,610.33	3,189,755.00	215.7		215.7	9,187,745.10	3,217,950.00	157.4		157.4	9,956,121.04	New York
North Carolina	1,880.5	4,043,812.37	1,929,554.29	128.4	35.3	163.7	1,085,177.46	522,629.59	61.5	12.5	74.0	4,016,658.14	North Carolina
North Dakota	4,593.3	1,687,309.34	843,558.81	224.5	128.1	352.6	1,580,837.89	789,029.50	231.9	160.4	392.3	2,352,779.58	North Dakota
Ohio	2,530.1	12,199,792.49	3,602,480.18	175.3	12.1	187.4	646,893.50	188,078.24	2.7	1.2	3.9	4,570,245.34	Ohio
Oklahoma	1,971.8	4,812,196.60	2,281,290.20	160.6	64.1	224.7	1,395,638.24	762,911.18	95.6	7.3	102.9	2,064,244.28	Oklahoma
Oregon	1,235.7	5,741,166.10	3,333,929.54	214.8	75.3	290.1	1,220,929.60	730,768.91	51.4	15.3	66.7	1,212,223.43	Oregon
Pennsylvania	2,658.1	7,243,177.79	2,578,577.96	46.5		46.5	291,261.75	96,440.55	3.4		3.4	6,139,980.76	Pennsylvania
Rhode Island	209.5	1,720,027.14	664,901.84	26.4		26.4						634,535.16	Rhode Island
South Carolina	1,861.3	5,788,980.02	2,348,730.43	89.3	131.4	220.7	2,866,792.38	1,407,832.01	17.0	96.9	113.9	60,387.03	South Carolina
South Dakota	3,791.2	2,859,896.27	1,581,874.04	280.8	75.4	356.2	704,791.35	387,635.14	101.2	19.7	120.9	2,264,998.01	South Dakota
Tennessee	1,418.4	2,381,619.76	1,189,171.16	114.9		114.9	680,049.15	340,024.55	19.7		19.7	3,372,654.37	Tennessee
Texas	7,048.8	11,558,153.38	4,865,251.49	521.3	112.8	634.1	3,781,610.50	1,765,442.77	171.2	114.7	285.9	8,812,881.81	Texas
Utah	1,039.4	956,654.15	707,479.21	80.8	17.2	98.0	868,013.68	465,770.63	40.9	55.9	96.8	1,311,778.92	Utah
Vermont	303.6	203,067.09	62,014.73	2.7		2.7						622,221.96	Vermont
Virginia	1,612.7	3,915,802.31	1,889,100.80	156.0	11.7	167.7	1,707,098.68	732,740.10	63.3	18.8	82.1	1,611,090.80	Virginia
Washington	1,002.0	2,711,179.17	1,161,400.00	43.4	36.3	79.7	1,530,760.31	760,084.70	63.5		63.5	2,121,175.86	Washington
West Virginia	757.6	4,262,214.73	1,573,535.06	110.4	12.2	122.6	891,774.73	370,049.78	12.1	.3	12.4	860,581.96	West Virginia
Wisconsin	2,468.3	3,320,068.72	1,456,000.00	81.8	15.5	97.3	179,803.32	85,000.00	8.8		8.8	2,597,754.71	Wisconsin
Wyoming	1,771.2	2,573,533.30	1,715,167.11	161.0	94.0	255.0	779,067.68	511,451.27	22.1	109.5	131.6	973,977.75	Wyoming
Hawaii	41.2	1,080,386.06	472,874.00	30.7		30.7	43,765.70	21,272.26	1.1		1.1	1,631,497.33	Hawaii
TOTALS	89,572.1	223,508,255.79	96,571,[illegible]64.28	6,957.3	1,855.0	8,812.3	80,911,823.88	35,450,099.41	2,566.5	1,162.1	3,728.6	130,223,875.73	TOTALS

[1] The term stage construction refers to additional work done on projects previously improved with Federal aid. In general, such additional work consists of the construction of a surface of higher type than was provided in the initial improvement.

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[1]The term stage construction refers to additional work done on projects previously [illegible]

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